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KACHEMAK BAY

A
STATUS REPORT

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KACHEMAK BAY

a

Status Report

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Anchorage

December 1975

KACHEMAK BAY

a

STATUS REPORT

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ABSTRACT

Results from continuous radar tracking of current drogues for periods as long as three weeks, show that the Bay has a complex circulation characterized by rather rapid flushing of the "Crab Sanctuary" and by a semi-permanent small counterclockwise eddy and larger clockwise eddy southward of a line drawn directly westwards from the tip of Homer Spit. Residence time of the waters within the Bay appears to be 20 days at the most and the Bay must be considered as an input-output system with respect to the dispersal and settling of crustaceans larvae. Preliminary considerations of the transport processes strongly suggest that crustacean larvae spawned outside the Bay will settle in the Bay and that larvae spawned in the Bay will be flushed to settle outside the Bay.

Preliminary results of sampling to determine the extent and patterns of settling of the first benthic stages of king crab larvae suggest a strong preference by the post larvae to settle on stony bottoms heavily encrusted with bryozoams (Flustrella) sponges, hydroids and other epifaunal mats.

The macrophyte ecosystem studies show diverse, abundant red, brown, green algal assemblages exhibiting well defined intertidal and subtidal zonations. Preliminary results show marked seasonal variations in growth and densitities of Alaria and other species, as well as in the utilization of the macrophyte environment by juveniles and adult king crabs, pandalid shrimps, dungeness crabs, and various fishes usually closely associated with the algal environment.

Analysis of current literature shows that sufficient information is available to describe the potential behavior, fate and impacts of various types of spilled petroleum products. The 250,000 barrels METULA spill of August 1975 in the Straits of Magellan, in a marine environment very similar to the Kachemak Bay - Lower Cook Inlet one, can be used to directly gauge the magnitude and extent of impact that could accrue from mishap involving the 125,000 to 500,000 barrels capacity of tankers presently plying the waters of Cook Inlet.

Analysis of current agencies statutory and regulatory practices indicate that, while technology is presently available and the body of environmental protection laws considerable, application of such technologies and laws is not as effective as it should be to protect and maintain the quality of the marine environment.

The fate of Kachemak Bay cannot be divorced from the fate of Lower Cook Inlet; both areas form an environmental/ecological unit of prime quality and productivity. The long term attributes of the biological resources and of their rapidly accruing values to the citizens of the state must be viewed in terms of a total "energy budget" between "non-renewable (oil and gas) energy resources" and "renewable (biological) energy resources."

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INTRODUCTION

Kachemak Bay, an area rich in scenic beauty and natural resources, has become a center of symptomatic controversies between environmental, fisheries and oil and gas interests, symptomatic because the story of Kachemak Bay will be the story of many other areas of coastal Alaska, as the quest for nearshore and offshore mineral resources development escalates.

Kachemak Bay is unique in that, within a few hundred square miles of coastal waters are concentrated high natural scenic beauty, rich and diverse biological resources, sheltered waters that can accomodate large ocean going vessels as well as rowboats, recreational facilities easily accessible from Alaska's largest metropolitan area, potentially highly renumerative oil, gas and coal deposits, thriving shellfish and fin fish fisheries, all within sight of a potentially eruptive volcano.

Kachemak Bay is not quite the kind of "pristine' coastal environment readily found within a few miles from its shore, but is an area of still prime environmental quality and productivity. Human impacts are localized and minimal, and much of current human activities can still assimilate within the natural, controlling environmental processes. Human impacts are visible, but again localized and with proper planning, foresight and fortitude can easily be repaired and controlled.

The intent of the present status report, the first of a series dealing with environmental and resources management, conservancy and protection issues for the Kachemak Bay - Lower Cook Inlet area, is to discuss and summarize salient findings emerging from ongoing field studies and analysis of current literature as they relate to man's disruption of the marine environment, especially by oil and gas related activities.

The present document reports on some of the results of work in progress, with the realization that, with the rapidly escalating tempo of oil and gas activities in the Lower Cook Inlet area, the continuing needs for "real time" management, protection and control actions necessitate immediate application of best integrated available knowledge, without waiting for the benefit of completed studies.

Environmental studies, such as transport mechanisms as they affect the distribution of crusteacean larvae or of pollutants, require not less than one full seasonal cycle of observations or about 18 months of measurements before some assessment of the dynamics of the system can be made. The first results of the Kachemak Bay studies initiated during the summer of 1974 are beginning to emerge. The results are rewarding as they already challenge some of the prevailing concepts on the mechanisms of distribution of crustacean larvae in the area. The results are challenging in that current published knowledge can provide for a pragmatic assessment of fate, behavior and impact of petroleum intruding into the environment of the Bay. The results are especially challenging in that they can already point at a course of action that can effectively protect the quality of the Bay as well as provide for a comprehensive management of its resources.

Marine Research in Kachemak Bay

A number of investigations have been conducted in Kachemak Bay by various agencies including the U. S. Fish and Wildlife Service, Bureau of Commercial Fisheries, National Marine Fisheries Service, University of Southern California, University of Alaska, and the Alaska Department of Fish and Game. Most of the research was until recently aimed at stock assessment. The Kachemak Bay Program has started the initial emphasis towards establishing an ecosystem approach to assessment of conditions and ecological relationships. A brief listing and description of some of the studies which have taken place in Kachemak Bay follows:

Year	Agency	Project
1941	USFWS	Otter trawl survey - located areas with commercial potential for king crab, tanner crab, and dungeness crab. Also noted bottom fish concentrations.
1957-59	University of Southern California	King crab research - studied movements and migrations; basic life history in Kachemak Bay.
1958;63	BCF	Shrimp exploration - located commercial populations of pandalid shrimp in Kachemak Bay
1961-63	BCF, ADF&G	King crab research - tagging operation in Kachemak Bay and lower Cook Inlet. Determined stock mixing and migration. Crab from Shelikof Straits recovered in Kachemak Bay during breeding season.
1962-75	ADF&G	Pink salmon escapement/return relationships studied, forecast program developed.
1963	ADF&G	Dungeness crab tagging; determined movements between upper and outer Kachemak Bay.

Year	Agency	Project
1968	ADF&G; BCF	Scallop exploration in Kachemak Bay, revealed scallops present but not abundant in quantities to support large trawl operation.
1969	Westinghouse Research Lab	Underwater TV survey in Kachemak Bay, scallop bed located plus areas of shrimp concentration.
1970-75	NMFS; ADF&G	Annual trawl surveys for shrimp species composition, distribution, and abundance.
1971-72	NMFS	Studied distribution of larval shellfish forms in Kachemak Bay. Bluff Point found to be major larval release and rearing area for king crab, shrimp, and tanner crab.
1971-75	ADF&G	King and tanner crab tagging to determine movements and migration patterns. Adult crab, after breeding in Kachemak Bay, moved to other areas in lower Cook Inlet.
1971-75	University of Alaska	Basic research on king crab physiology.
1972-75	ADF&G (F.R.E.D.)	Assessed potential for saltwater rearing of salmon in Kachemak Bay.
1972	ADF&G	Tagging of pink salmon in Kachemak Bay to determine movements and migration rates.
1973-75	NMFS	Basic research to describe larval forms of Pandalid shrimp.
1974-75	ADF&G	King and tanner crab pot index surveys for distribution relative abundance of stocks, and year class strength.
1974	ADF&G	Scallop exploration in Kachemak Bay. General information on distribution obtained.

Year	Agency	Project
1974	ADF&G (S.F. Div.)	Hardshell clam inventory and distribution study in Kachemak Bay.
1974	Halibut Comm.	Distribution and relative abundance of halibut studied through trawl survey.
1974-75	ADF&G (Dames & Moore)	Ecological relationships studied in intertidal and near shore subtidal areas of Kachemak Bay with emphasis on macrophyte (kelp) communities. Base-line date collected.
1974-75	ADF&G	Current movements studied in Kachemak Bay as related to larval transport. Show more complex and variable circulation patterns than previously assumed.
1974-75	NMFS/Auke Bay	Bioassays performed on juvenile shellfish using Cook Inlet crude oil. Low levels of oil induced mortalities on early life forms.
1975	ADF&G	Larval timing and distribution; benthic biology studied. Early settling stage king crab found in Bluff Point area as well as south side Kachemak Bay.
1975	USFWS; Rutgers University	Study of salt marsh communities in Kachemak Bay. The senior scientist, Dr. Crow stated that on a per unit area basis, Kachemak Bay is one of richest areas he has ever studied.

This list is by no means complete; however, it provides for an overview of the main ecological/biological investigative programs presently in Kachemak Bay. It is interesting to note that very little research has been directed toward herring, bottom fish, or clam resources in Kachemak Bay.

SECTION I

THE MARINE ENVIRONMENT

OF

KACHEMAK BAY

SECTION I

THE MARINE ENVIRONMENT OF KACHEMAK BAY

General Description

Kachemak Bay is an elongated embayment contiguous to the southeastern entrance to Cook Inlet (Fig. 1). The bay is about 45 miles long (about 67 km) and about 22 miles wide (about 33 km) at its western approaches between Anchor Point and Pt. Pogibshi. The narrow, 4 miles long (about 7 km) Homer Spit projects about 1/2 way through the central width of the bay, separating the bay into an outer and inner bay.

The sea floor and shore topography of Kachemak Bay reflects the sudden transition between the mountainous, highly indented coastal terrains of the Gulf of Alaska Coast, and the gently rolling coastal terrain bordering the eastern side of Cook Inlet.

The northern shore of the bay is fronted by an extensive shallow platform, well defined (in the outer bay) by the 20-30 fathoms contours and by the 10-20 fathoms contours (in the inner bay) (Fig. 2). Extensive tidal shallows and mudflats are found along the eroding - slumping cliffs and bluffs of the northern shore.

The inner head of the bay is characterized by the extensive tidal flats, braided drainages and marshlands of the Fox River complex, a major drainage outlet for the mountainous terrain and ice fields bordering the coast; the greatest portion of the drainage from the SW sector of the Kenai Mountains separating Kachemak Bay from the Gulf of Alaska flows into Kachemak Bay, an important factor which greatly controls the seasonality of the estuarine regime of the bay.

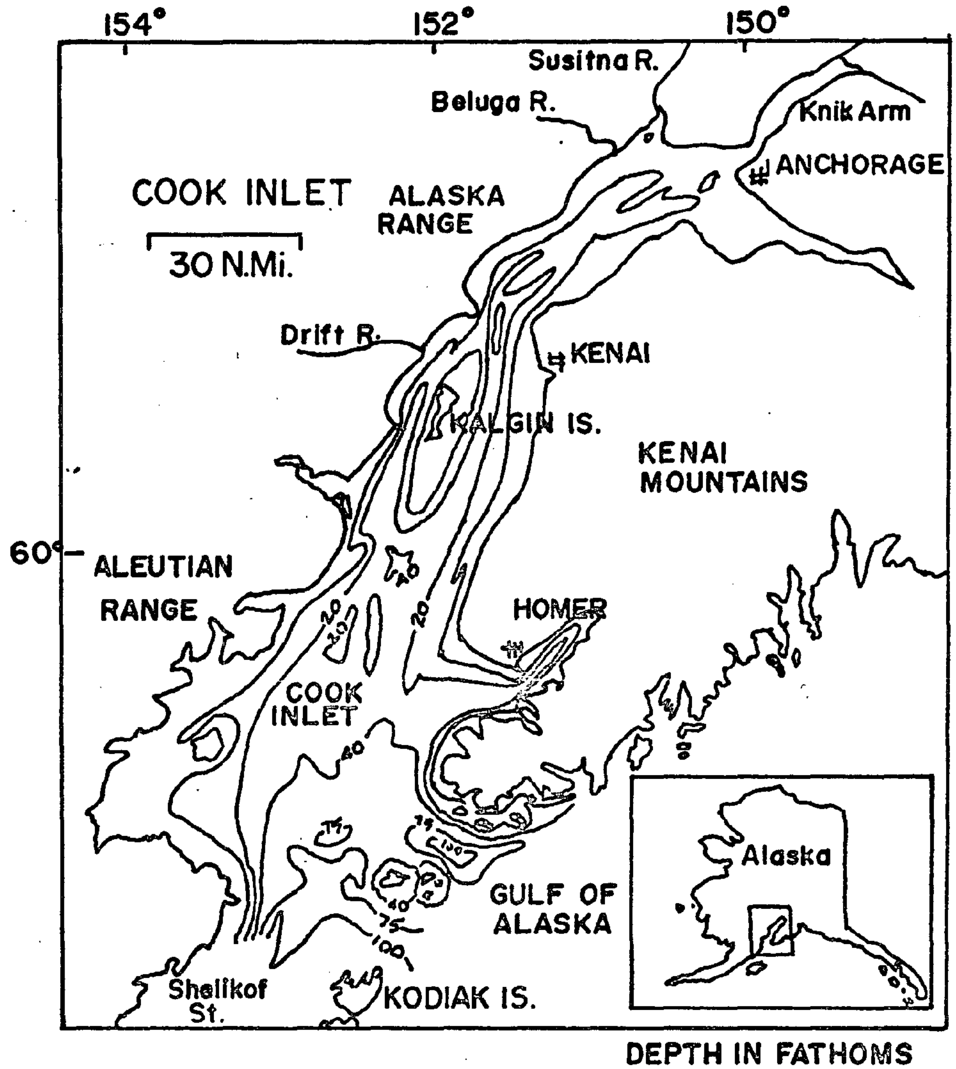


Fig. 1 GENERAL BATHYMETRY – COOK INLET

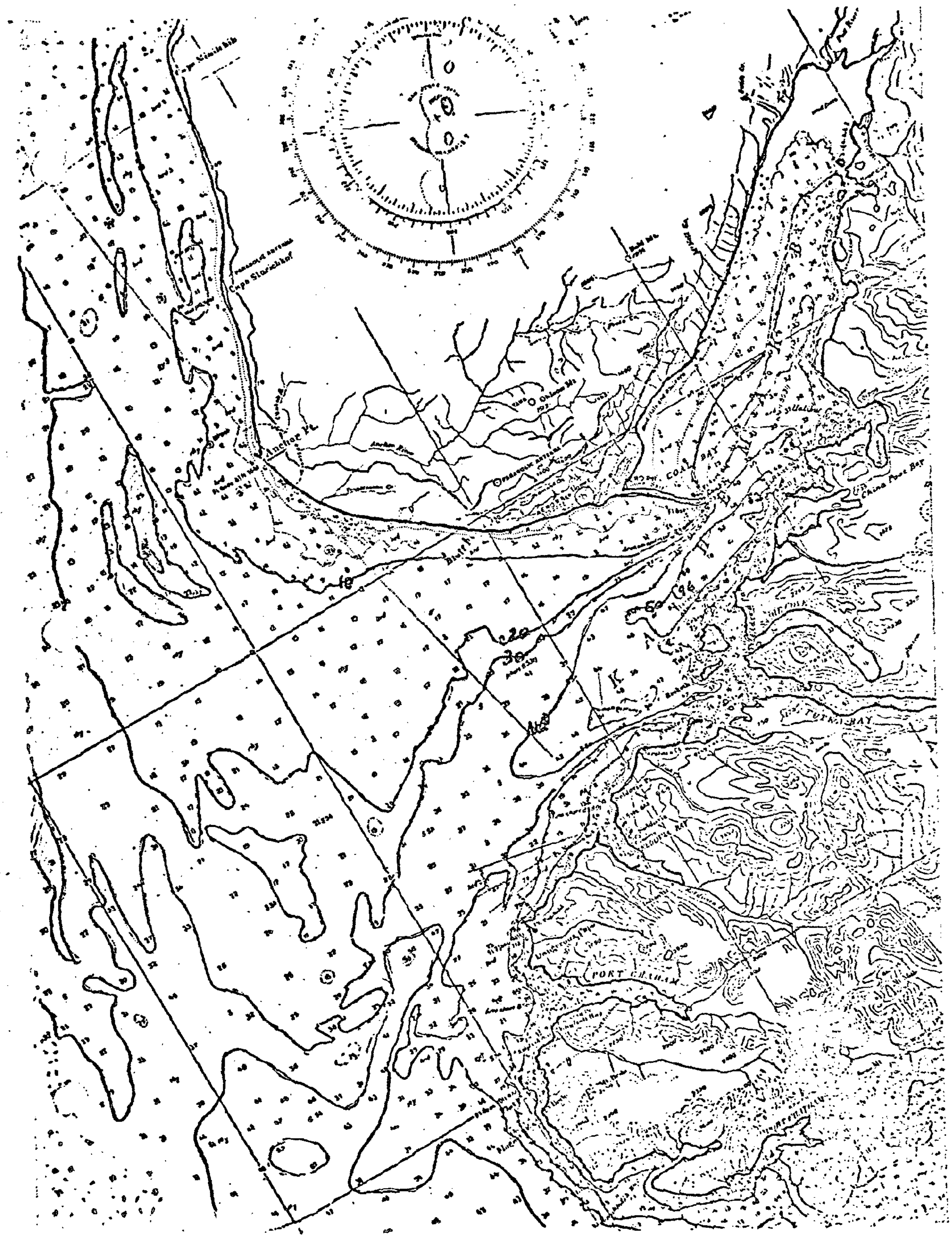


Fig. 2 - General Bathymetry - Kachemak Bay and approaches

The southern shore of the bay is characterized by a mountainous, dissected coast, fronted by the remnant of a glacially carved trough; depths in excess of 30 fathoms extend from almost the head of the bay to the main channel of Cook Inlet.

The deepest waters of Kachemak Bay center between Halibut Cove and Yukon Island. Depths slightly in excess of 80 fathoms are found off Gull Island, SW from the tip of Homer Spit and about 95 fathoms, the deepest portion of the bay is found off Cohen Island.

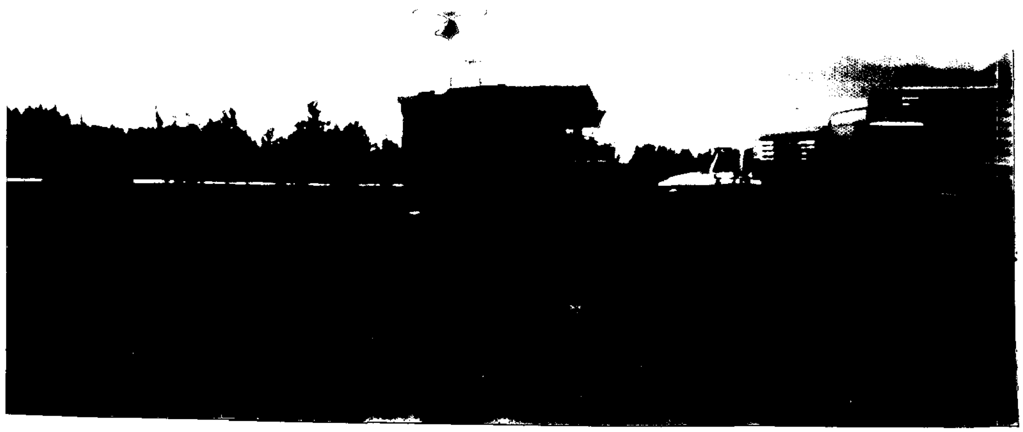
Circulation

The circulation of Kachemak Bay has been variously investigated by Bright et al (1960), Knull and Williamson (1969), NOAA (1973, 1974), ADF&G (1974, 1975). The direct flow measurements usually fall into two main sampling techniques: Lagrangian (pathlines) performed with drifting devices (drift cards, current drogues), and Eularian (single point) performed with moored current meters.

Apart from the recent current measurements performed by NOOA and ADF&G, most of the available data were of short duration, encompassing at best a few hours to a few tidal cycles. The 1973 NOOA Eularian measurements collected at the entrance of Kachemak Bay at a location midway between Anchor Point and Pt. Pogibshi covered a period of about 18 days of continuous measurement of surface, midwater and near bottom currents. ADF&G Lagrangian measurements to date continuously sampled over periods in excess of 23 days.

The ADF&G studies initiated in 1974, are specifically designed to better define the long terms transport mechanisms of the bay. The prime objective is to correlate the onset of spawning, duration of planktonic larval stages and timing of first bottom settling of crustacean larvae. The Kachemak Bay area, especially the outer bay, is well recognized as being one of the most important breeding, spawning and reproduction center for commercially important crustaceans. Much inferences have been made about the occurrence of a "gyre" that concentrates the spawn and larvae and the ADF&G long term transport measurements were specifically designed to update the rather fragmentary information on the local circulation.

To overcome the problems of vessels availability, scheduling, costs and sea keeping capabilities a shore based radar tracking technique of "current drogues" is being used. The technique consists of continuously tracking, by means of a standard marine radar (Decca), the motion of radar reflectors mounted on a surface float tethered to either 6' X 6' canvas biplanes or to personnel or cargo parachutes deployed at various depths. The technique has proven to be highly effective for continuous monitoring of the circulation over the entire bay. The radar is mounted on a truck and can moved from location to location in accordance with changes in tracking requirements.



Tracking offshore drogues, Bluff Point

Early morning radar watch

A highway overlook at Bluff Point has proven to be a most advantageous location, the elevation enabling better than a 25 mile range for tracking of drogue reflectors. Better than 8 drogues, each programmed to sense currents at different levels, can easily be tracked, around the clock. Tidal periods continuously sampled during the course of the present investigation are shown in figure 3.

The results obtained so far, show that the circulations of the bay is complex reflecting the combined influence of the diurnal and monthly lunar inequalities of the tidal forces, seasonal changes in tidal regime, meteorological effects and runoff fluctuations. (Fig. 4, 5, 6)

Preliminary analysis of the drogues data show:

Period 8 - 11 May 1975

Drogue trajectories for this period are shown in Fig. 7. The surface drogues released in and near the mouth to the inner bay moved rapidly seawards, drifting in a northwestern along the northern shore of the outer bay. The drogue movement near the mouth of the bay may reflect a general net outflow of relatively fresh water at the surface, and the net inflow of more saline water at depth. Such a circulation is typical of many estuaries, particularly during periods of high runoff. Subsequent drift up coast developed a sawtooth pattern as a result of the flood and ebb impulses superimposed upon the net northwestward transport of surface waters.

Period 27 May - 3 June 1975

The generalized drogue trajectories and the inferred circulation for this period are shown in figures 8, 9, and 10. Tides were changing from spring to neap, (figure 3). Although the period of observation was short, evidence is strong to support the presence of a counterclockwise gyre extending throughout the water column of the outer bay. Surface waters ingressed into the bay along the southern shore moving seawards along the

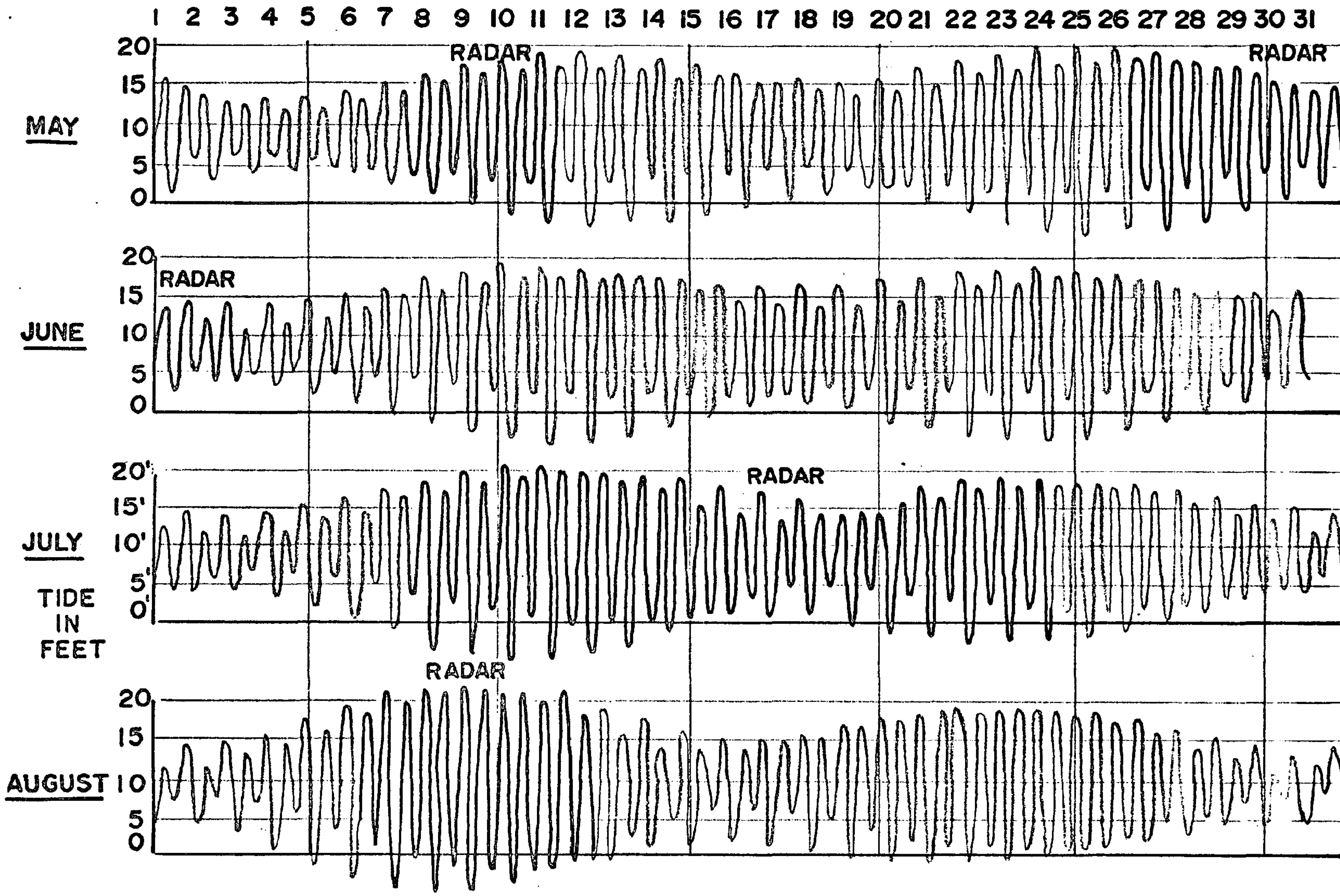


Fig. 3

TIDAL HEIGHTS

MAY – AUGUST 1975

RADAR TRACKING DARK

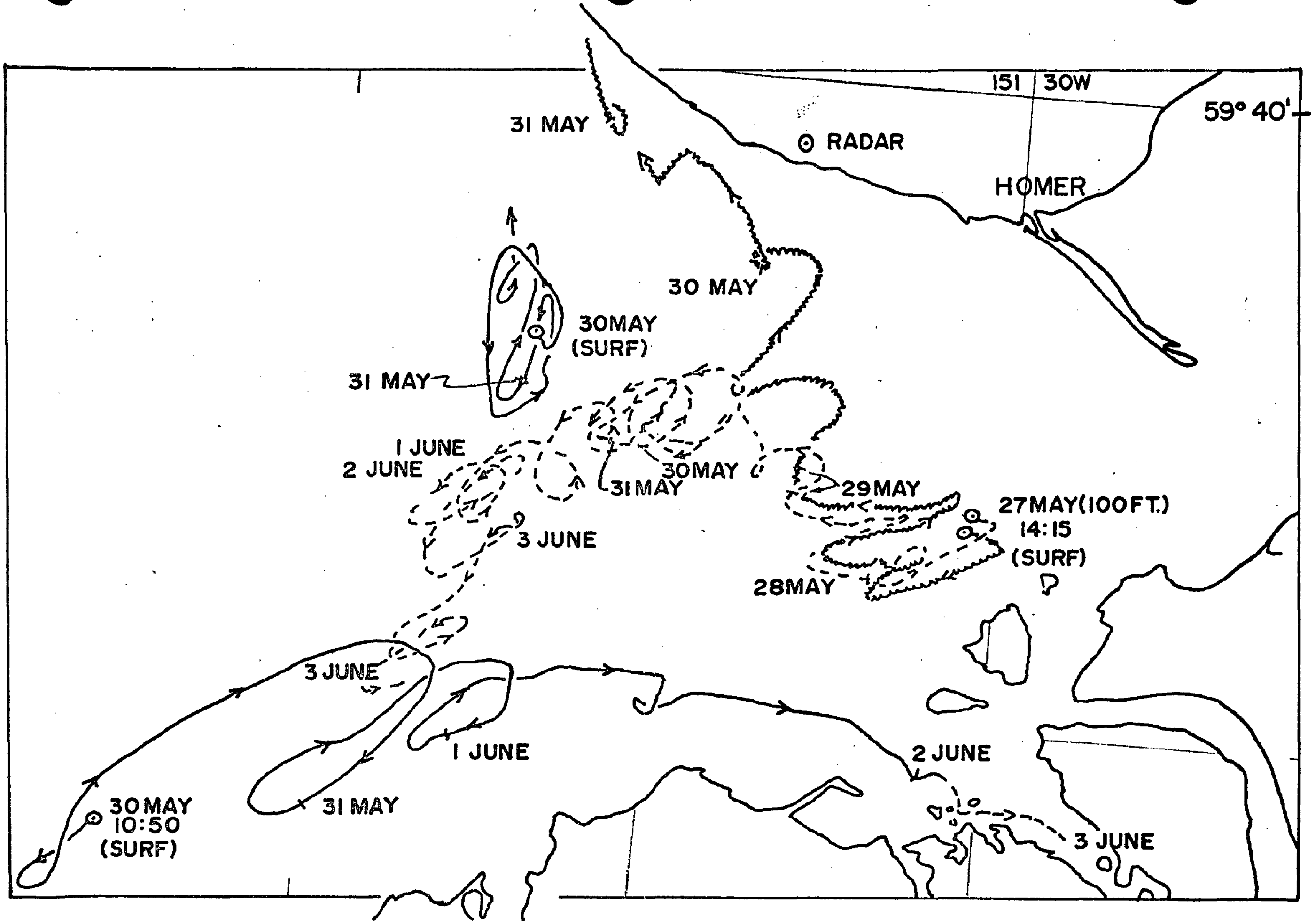


Fig. 4 - Drogue Drift, 27-31 May 1975

KACHEMAK BAY
CURRENT DROGUES

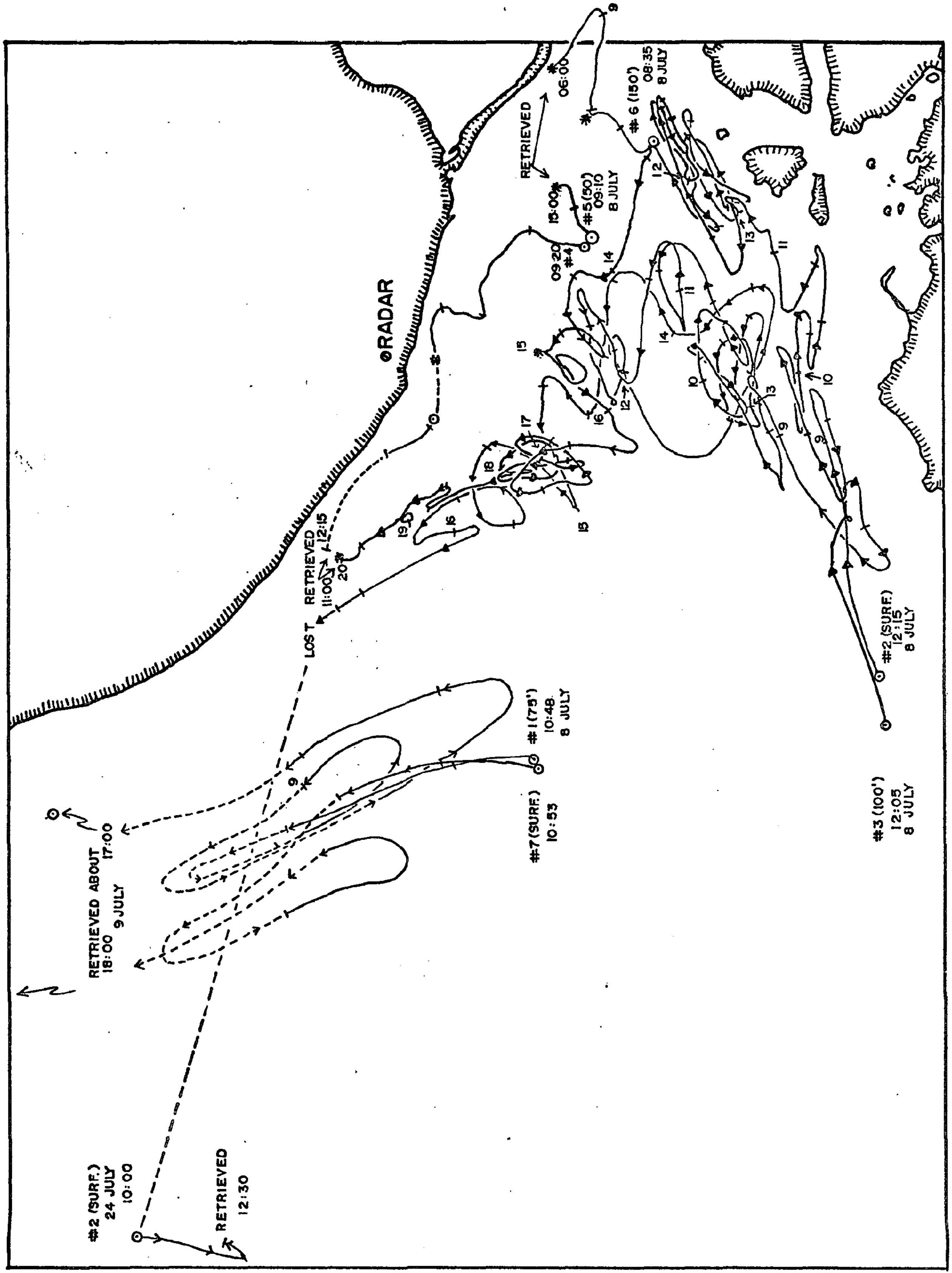


Fig. 5 - Drogue Drift, 8-24 July 1975

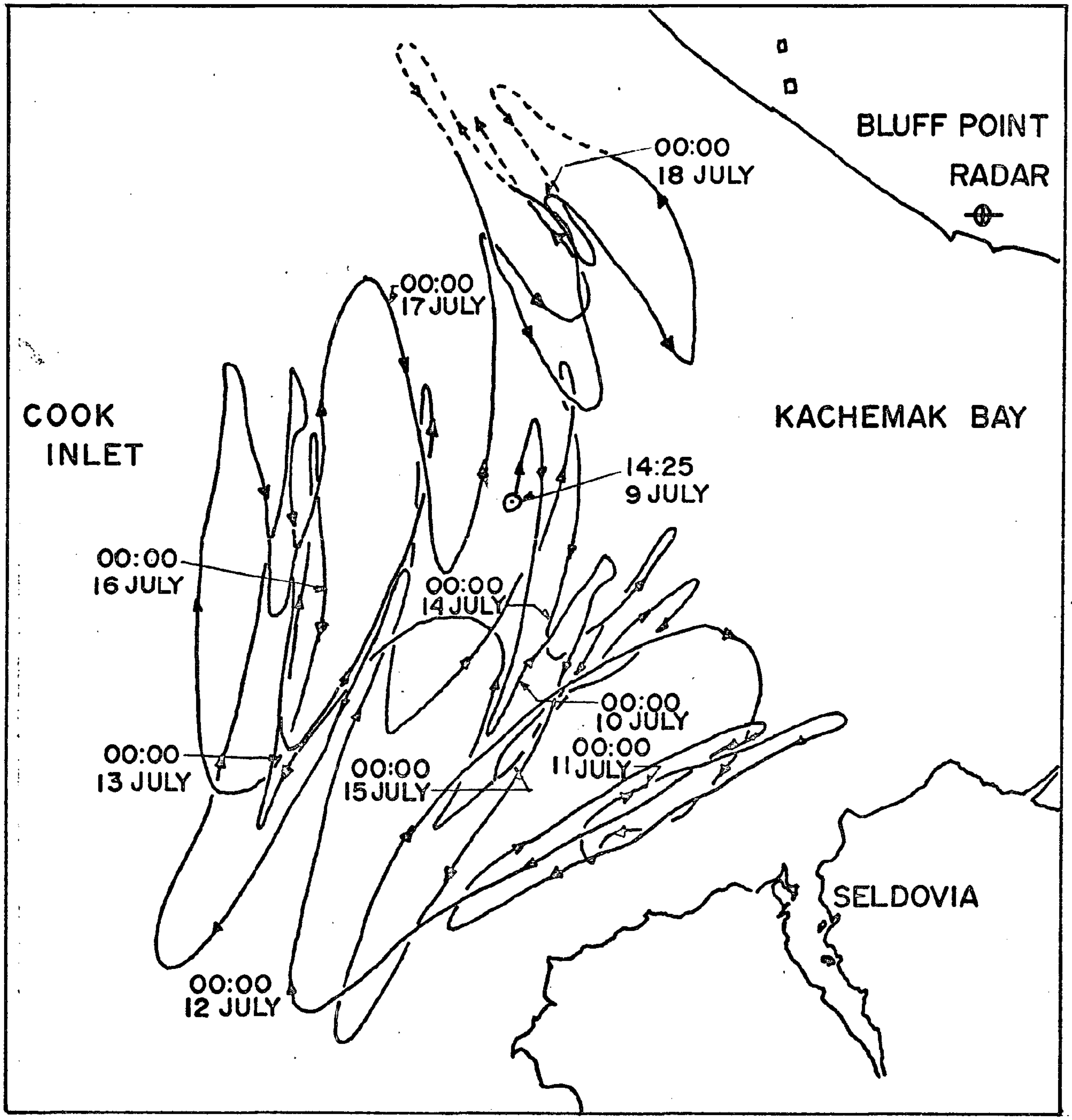


Fig. 6 - Drogue Drift, 9-18 July 1975

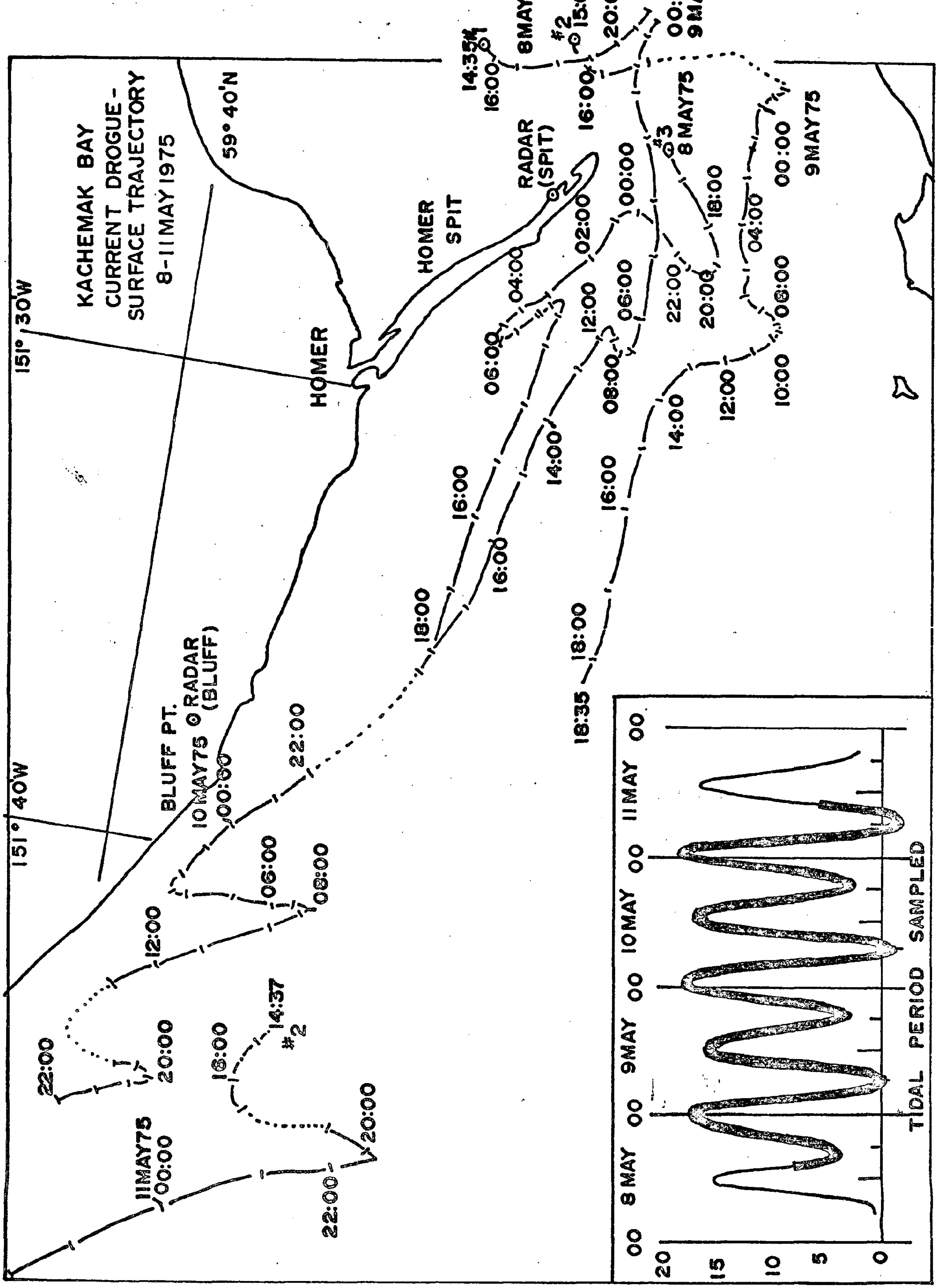


Fig. 7 - Drogue Drift, 8-11 May 1975

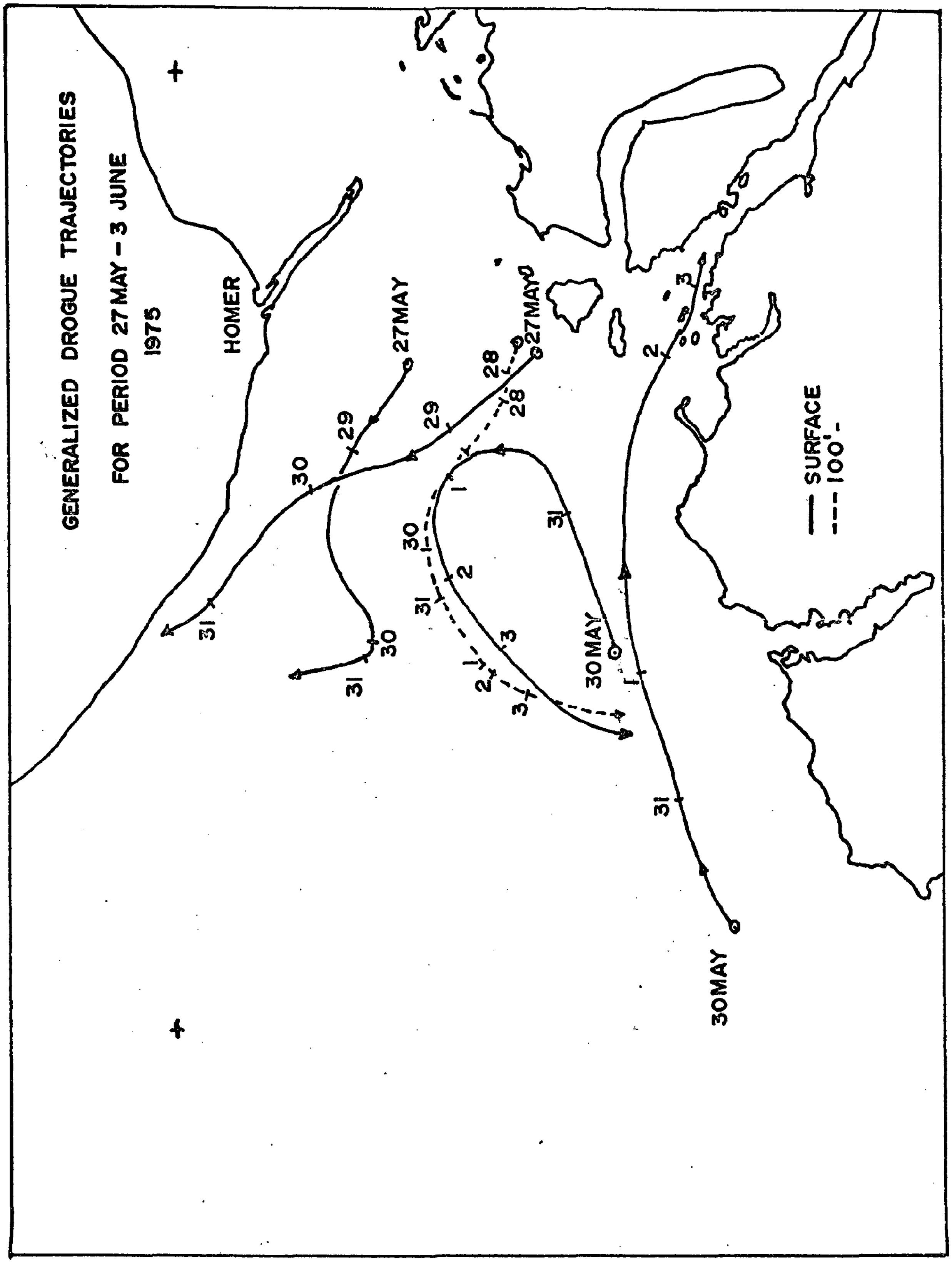
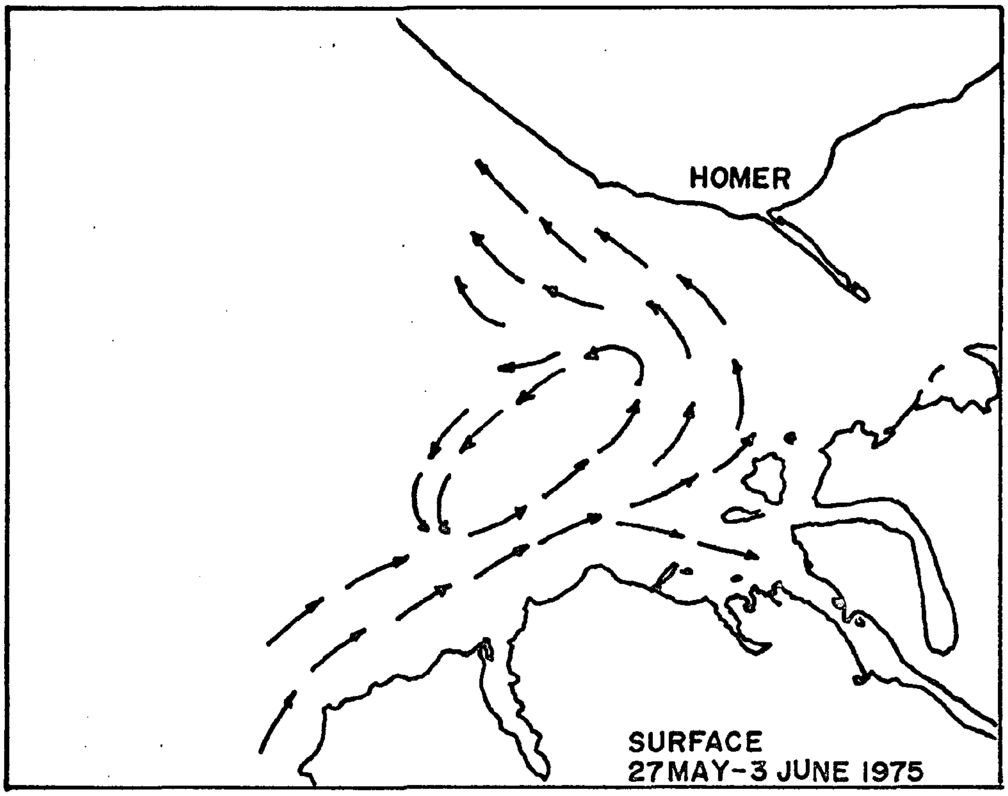


Fig. 8 - Drogue Trajectories, 27 May - 3 June 1975



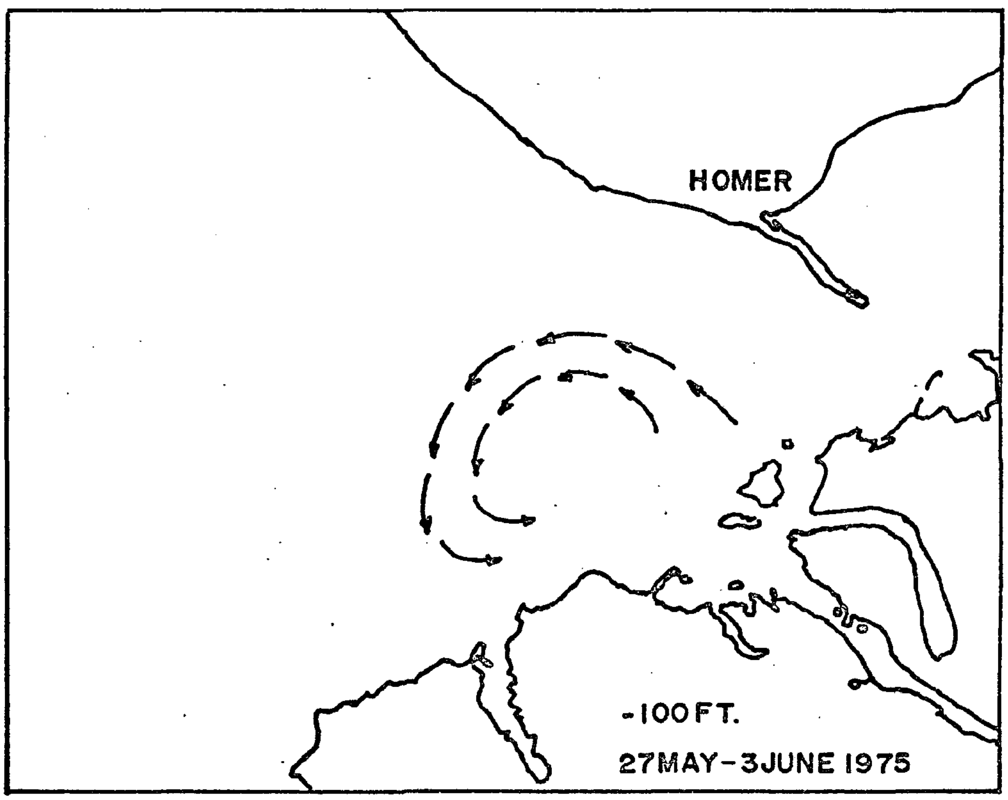


Fig. 9 - CIRCULATION PATTERNS — KACHEMAK BAY

27 MAY — 3 JUNE 1975

northern shore.

Subsurface circulation in the gyre appears considerably more sluggish than at the surface. The period (time required for transport once around the gyre) for the subsurface gyre (at 100' depth) appeared to be approximately 10-12 days, in contrast to about 5-6 days at the surface.

Period 8 - 24 July 1975

Generalized drogue trajectories and inferred circulation for this period are shown in figures 11, 12, and 13. During the period 8-20 July, the existence of a counterclockwise rotating gyre in the outer bay was evident, the gyre however, having moved several miles eastward into the bay; accompanying this was a larger clockwise rotating gyre to the west. This pattern persisted through the spring and neap tidal phases. However, with the onset of the following spring tide (21-24 July), the outer clockwise rotating surface gyre became enlarged and moved farther eastward into the outer bay, inducing a southwestward transport of surface waters to develop along the southern shore. The inner counterclockwise rotating surface gyre was either eradicted or displaced farther eastward into the outer bay; however data are insufficient to determine the exact sequence of events.

The heights or ranges of the two spring tides did not appear to be significantaly different to account for the observed variation in the current pattern, suggesting that other variables, as yet undefined, are probably quite important in determining the circulation pattern. The subsurface gyre persisted throughout the period 8-24 July.

Period 7 - 12 August 1975

The spring tides amplitudes for this period were significantly larger

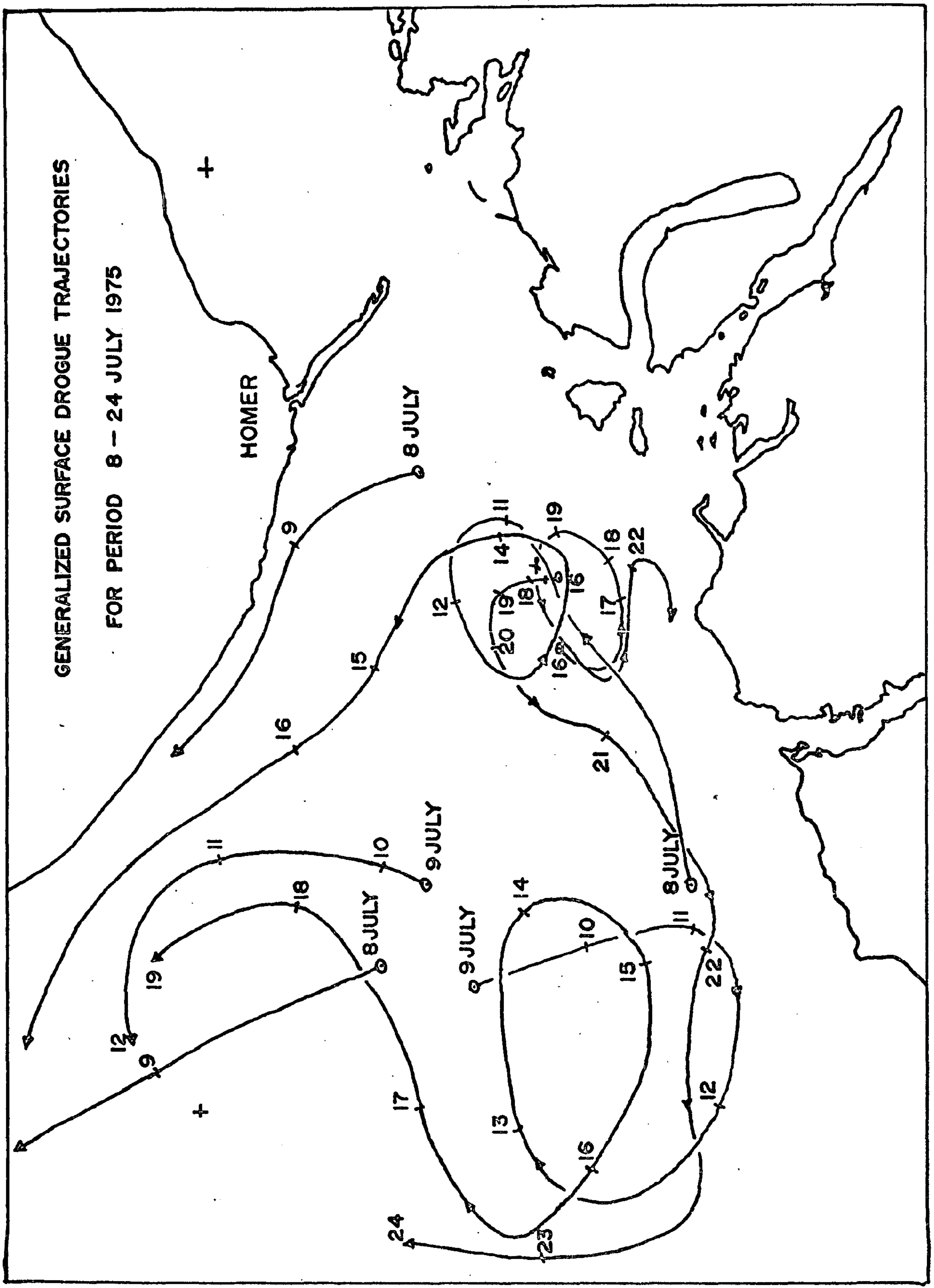


Fig. 10 - Drogue Trajectories, 8-24 July 1975

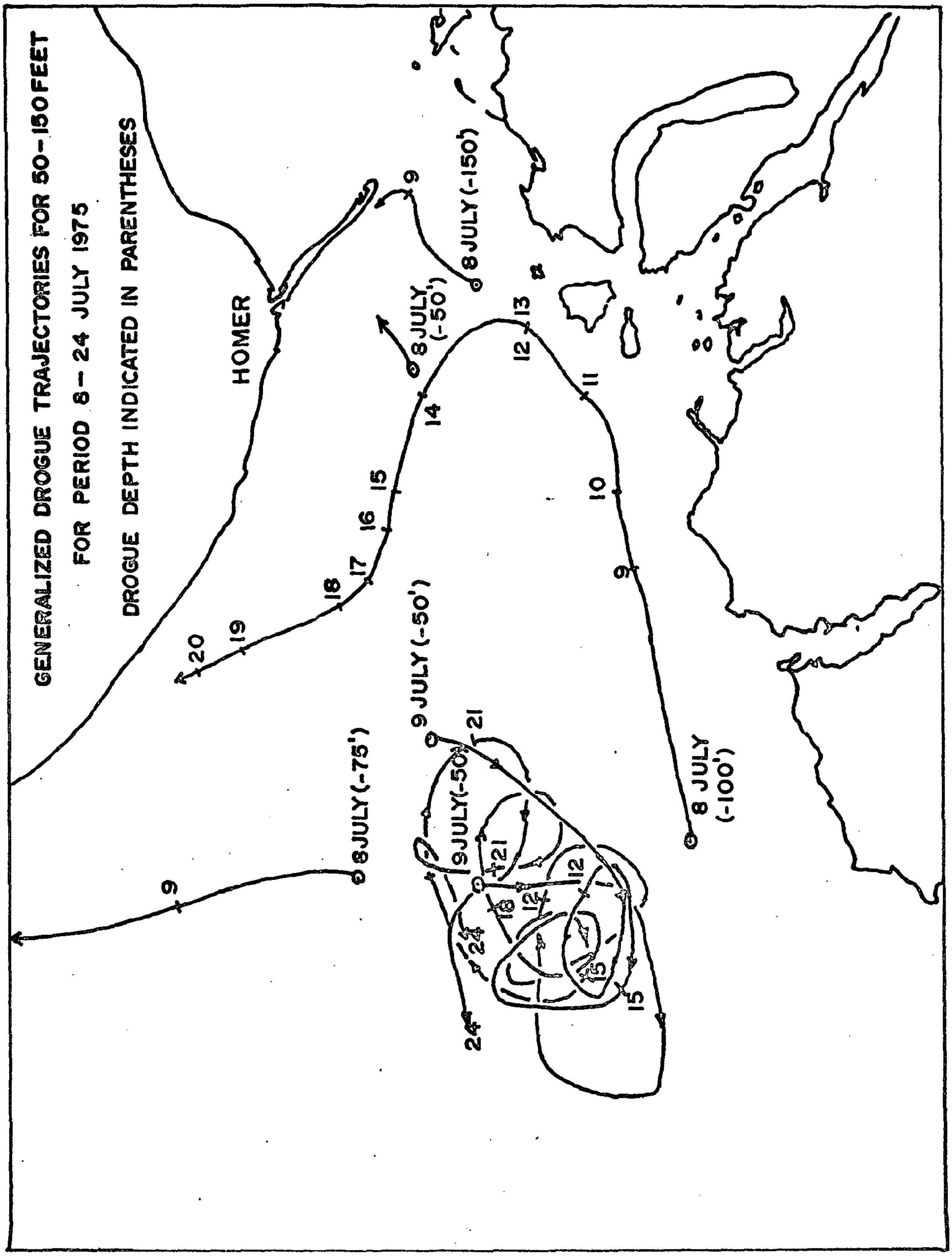


Fig. 11 - Drogue Trajectories, 8-24 July 1975

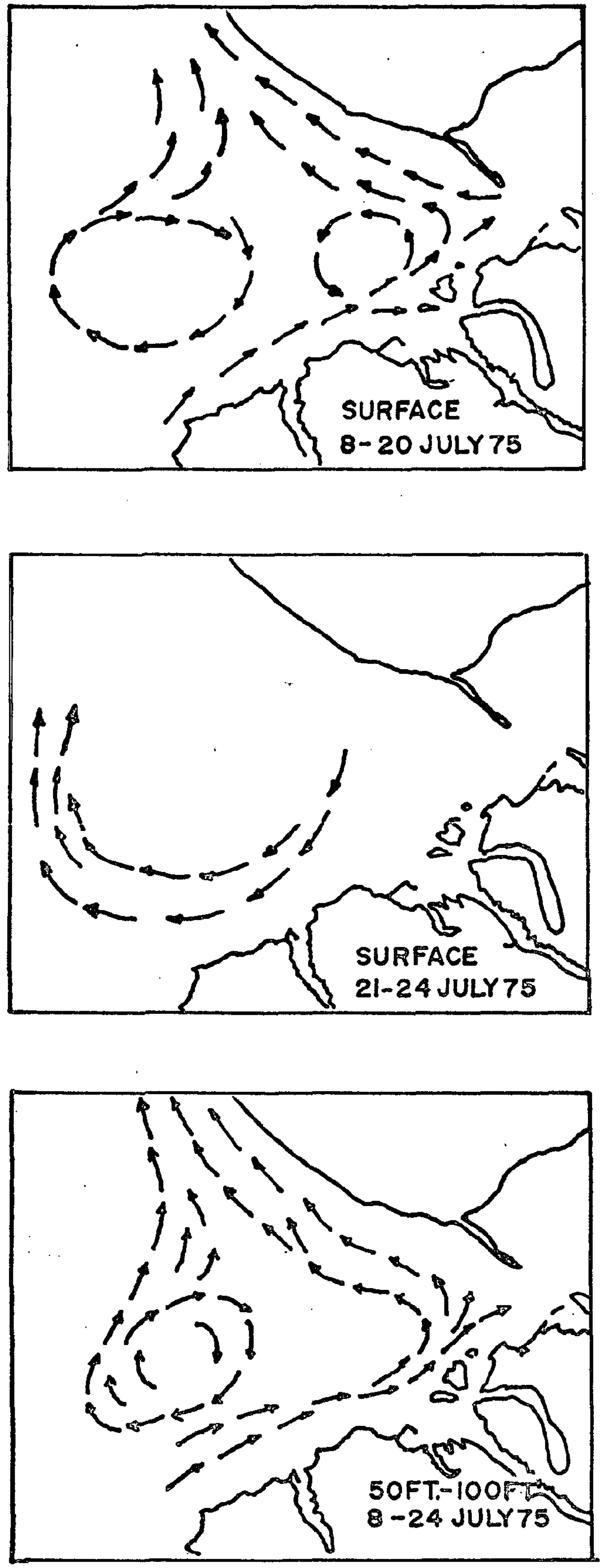


Fig. 12 - CIRCULATION PATTERNS - KACHEMAK BAY

JULY 7 - 25 1975

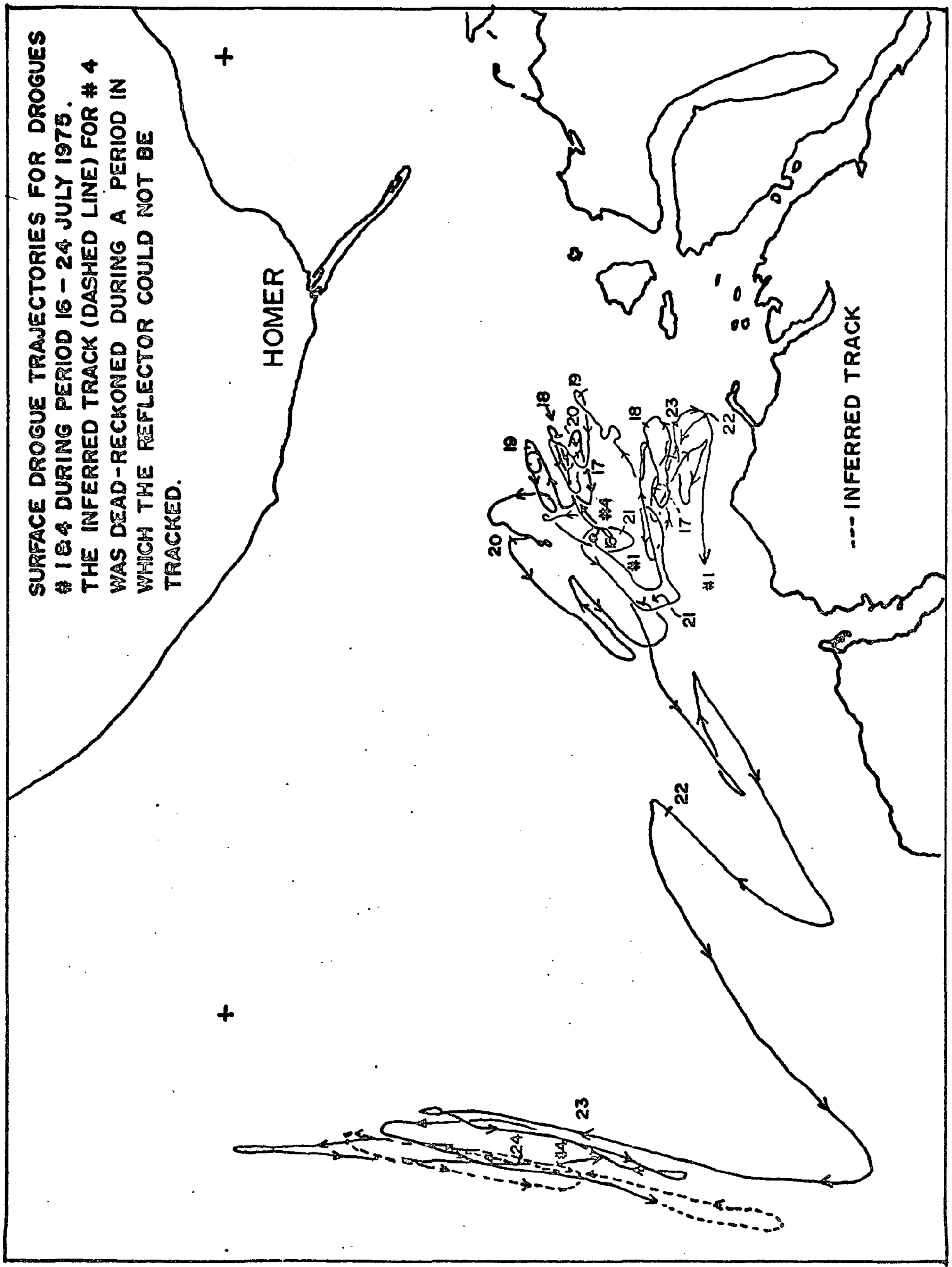


Fig. 13 - Drogue Drift, 16-24 July 1975

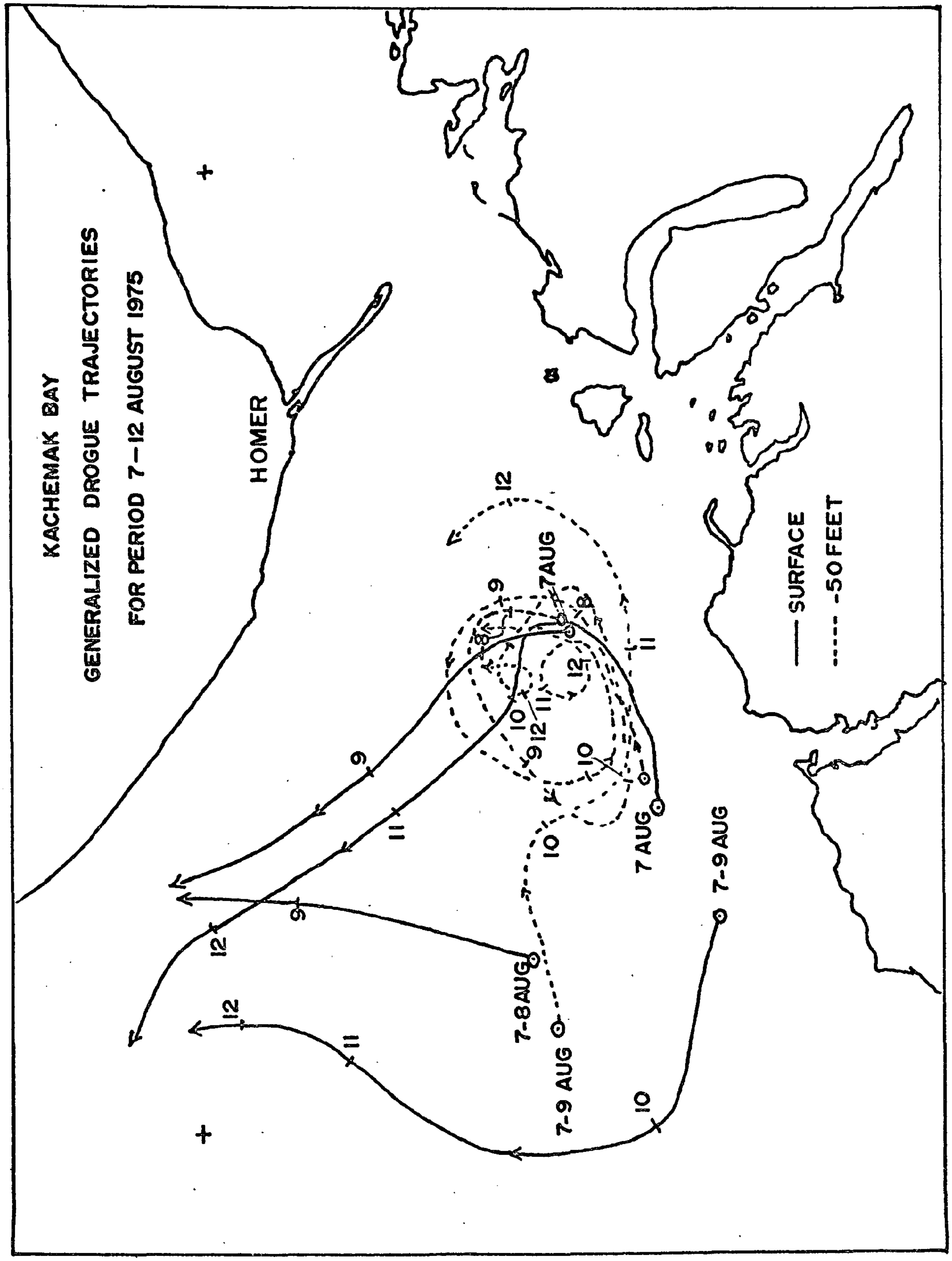


Fig. 14 - Drogue Trajectories, 7-12 August 1975

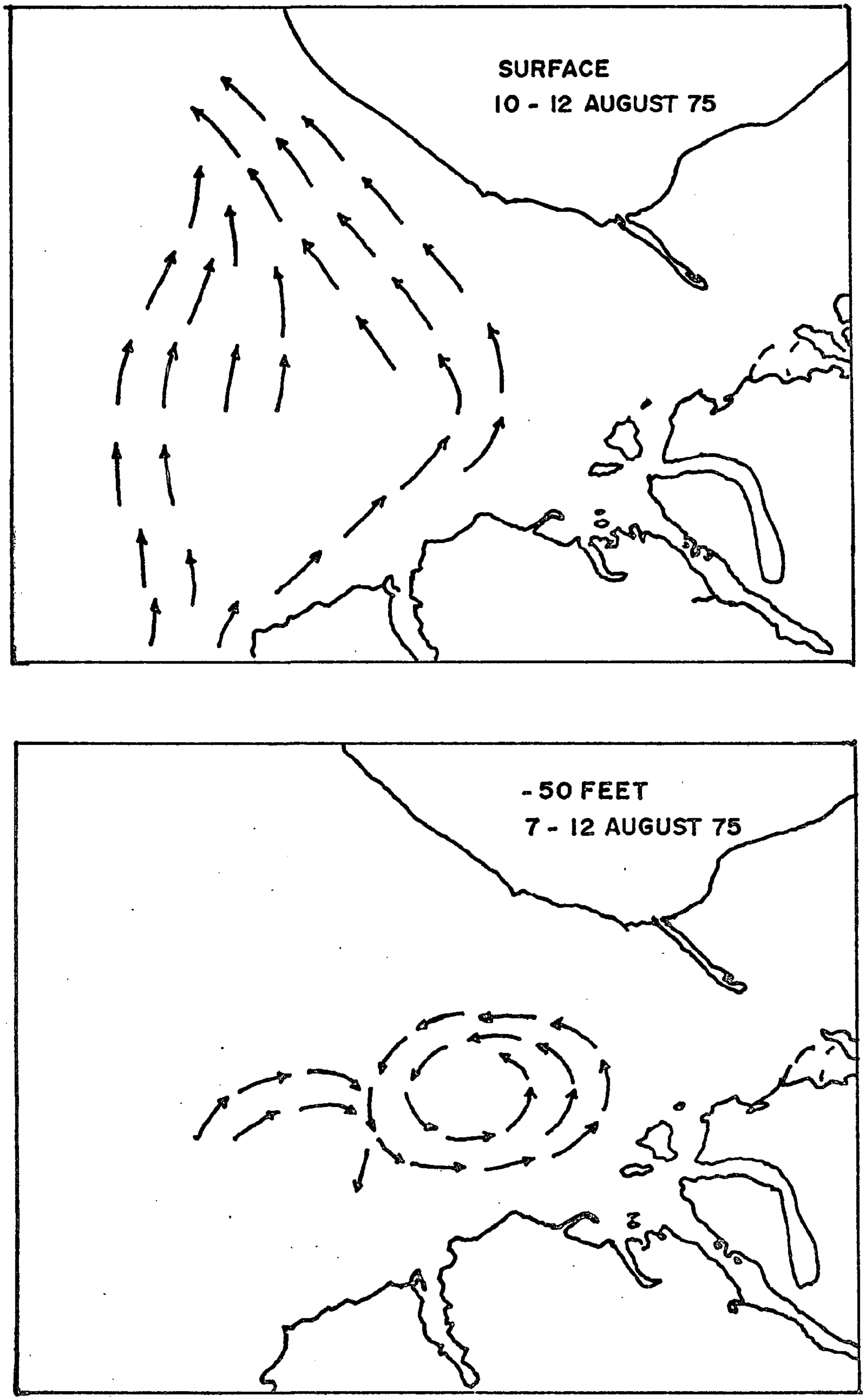


Fig. 15 - CIRCULATION PATTERNS - KACHEMAK BAY
7-12 AUGUST 1975

during the height of the spring tides. A well defined clockwise gyre was also present in the southeastern sector of the outer bay during the early phases of the spring tide, the resulting flow becoming incorporated into the general northward movement of the surface waters as shown in figure 13. Significant differences in flow patterns between the surface and the subsurface waters were observed during the period of large amplitude spring tides. In contrast to the events observed in the surface waters, the southeasterly subsurface counterclockwise gyre persisted throughout the period and showed no evidence of breaking down. A subsurface (50'), figure 14, drogue released farther offshore, along the margin of the clockwise gyre, moved eastwards and became incorporated into the inner counterclockwise gyre. The reverse of this flow transfer between gyres was observed during the 8-24 July period when a surface drogue transected from the inner to the outer gyre in the region where the two gyres coalesced (figure 15.).

Period 4 - 8 September 1975

During the sampling period a southwesterly gale with average wind velocities of approximately 20-30 kts developed on the evening of 4 September and continued unabated for three days until about midnight of 7 September. The actual drogue trajectories are shown in figure 16 and drogues B, 2, 5 & 6 released into the outermost reaches of the Bay, tended to remain in the area for a longer period than those released further eastwards in the more central portion of the outer bay, suggesting the presence of an eddy in the outer bay, or at least a more sluggish water movement in the outer reaches as compared to the inner portion of the outer bay. Drogues A, 1, 4 & 7 released in the eastern part of the

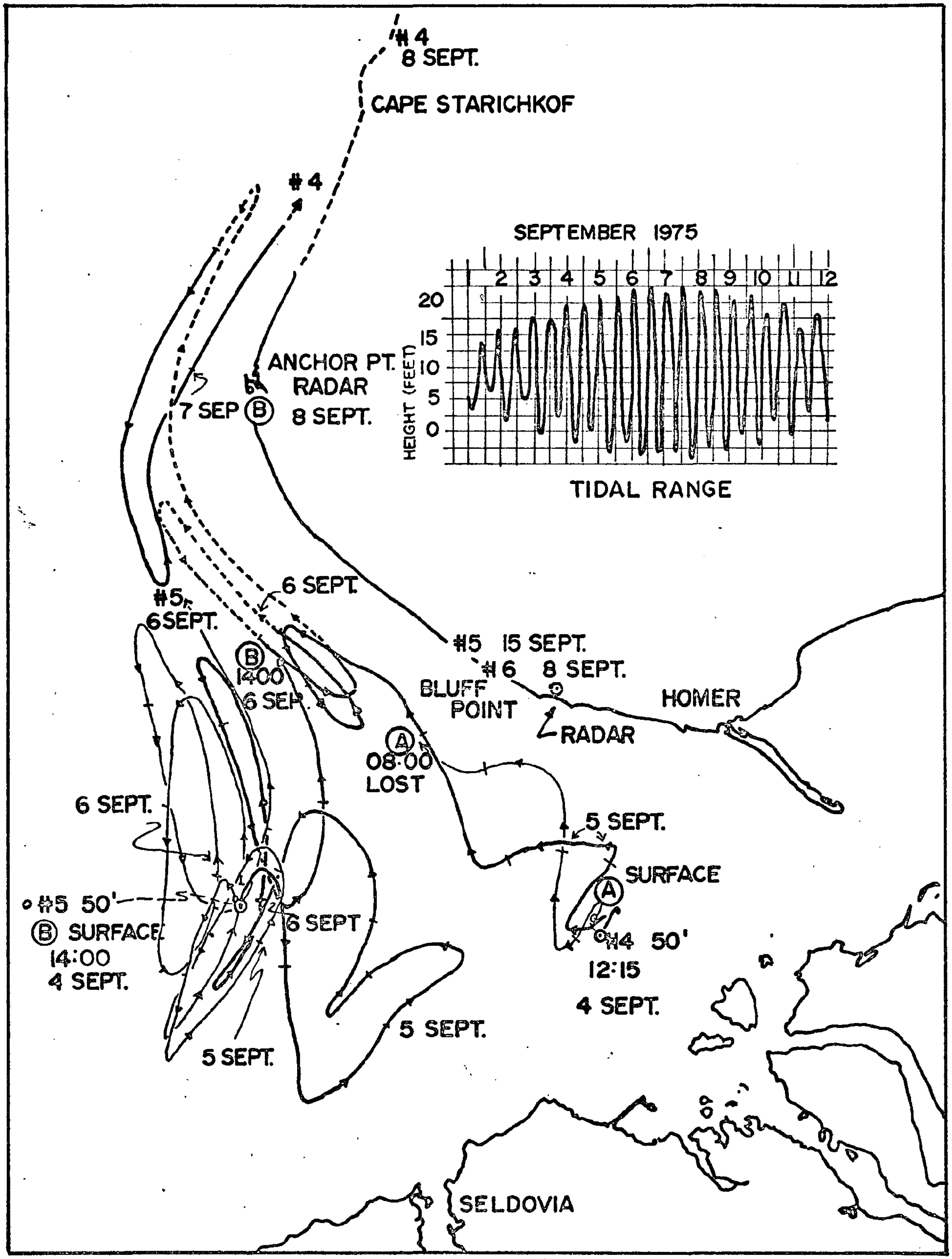


Fig. 16 - Drogue Drift, 4-8 September 1975

outer bay moved rapidly northwards and their drift behavior gave no indication of the counterclockwise gyre previously observed in the area.

Drift patterns suggest that by 6 September the southwesterly gale had induced a considerable acceleration in the northerly movement of the surface water down to at least 50', inducing net drogue movements as high as 10 n. mi./day. Direct wind drag upon the observed drift of the drogue; it is interesting to note however, that the drogue responded well to the cyclic reversal of the tidal flow.

The trajectories of drogues 5 and 6 are of particular interest. Both 5 and 6 were set at 50' and were being carried north well offshore when lost from radar view at approximately 1500 hrs on 6 and 5 September respectively. Both drogues, however, evidently reversed direction during the height of the gale and were carried southeast to Bluff Point where they washed ashore. (Aircraft reconnaissance located #6, washed ashore, on 8 September, and although # 5 was not located until 15 September (by local hunters), it's lack of detection by the 8 of September aircraft reconnaissance was apparently due only to its almost total destruction in the surf). Although exacting meterological data for the period of the gale have not yet been analyzed, it is unlikely that a change in wind direction could have induced the southeastward movement of the deeper drogues since the surface drogues in the same vicinity were not similarly affected. An interpretation of the observed drift patterns must await more detailed analysis of the meterological conditions imposed upon the Cook Inlet during the period of the survey. Such a compensatory current logically would intensify as the gale forced a pileup of surface waters in upper Cook Inlet. If such is the case, the southward flowing subsurface compensatory current was apprently strong enough by 6 or 7 September to carry the 50' drogues (5 and 6) south and east back into outer Kachemak

Bay with eventual grounding near Bluff Point. That the surface drogues in the same vicinity were not carried southeast also is strong evidence that the drogue movements were not dominated by wind influence on the above surface reflectors, but rather were produced by current drag on the drogues themselves. Why drogues 1 and 4 (both 50') were not similarly affected as 5 and 6 is not known. The grounding of the float reflector components of drogues 1 and 4 is undoubtedly due to the fact that their closer proximity to shore caused loss of their drogue assembly as they grounded over the shore fronting Anchor Point.

As shown in the inset of figure 17, drogue # 2 (surface) was again located by radar after the gale subsided and was observed to be moving in a westerly direction fron Ninilchik. Further observations of #2 however were curtailed due to radar malfunction. (Drogue/reflectors A, 2 and 7 have not yet been located or retrieved as of 4 October).

Present observations strongly suggests that winds have a profound effect on the net circulation of Kachemak Bay and Cook Inlet, and that transient events such as a gale may be most significant in controlling the transport and dispersal of planktonic larvae and pollutants.

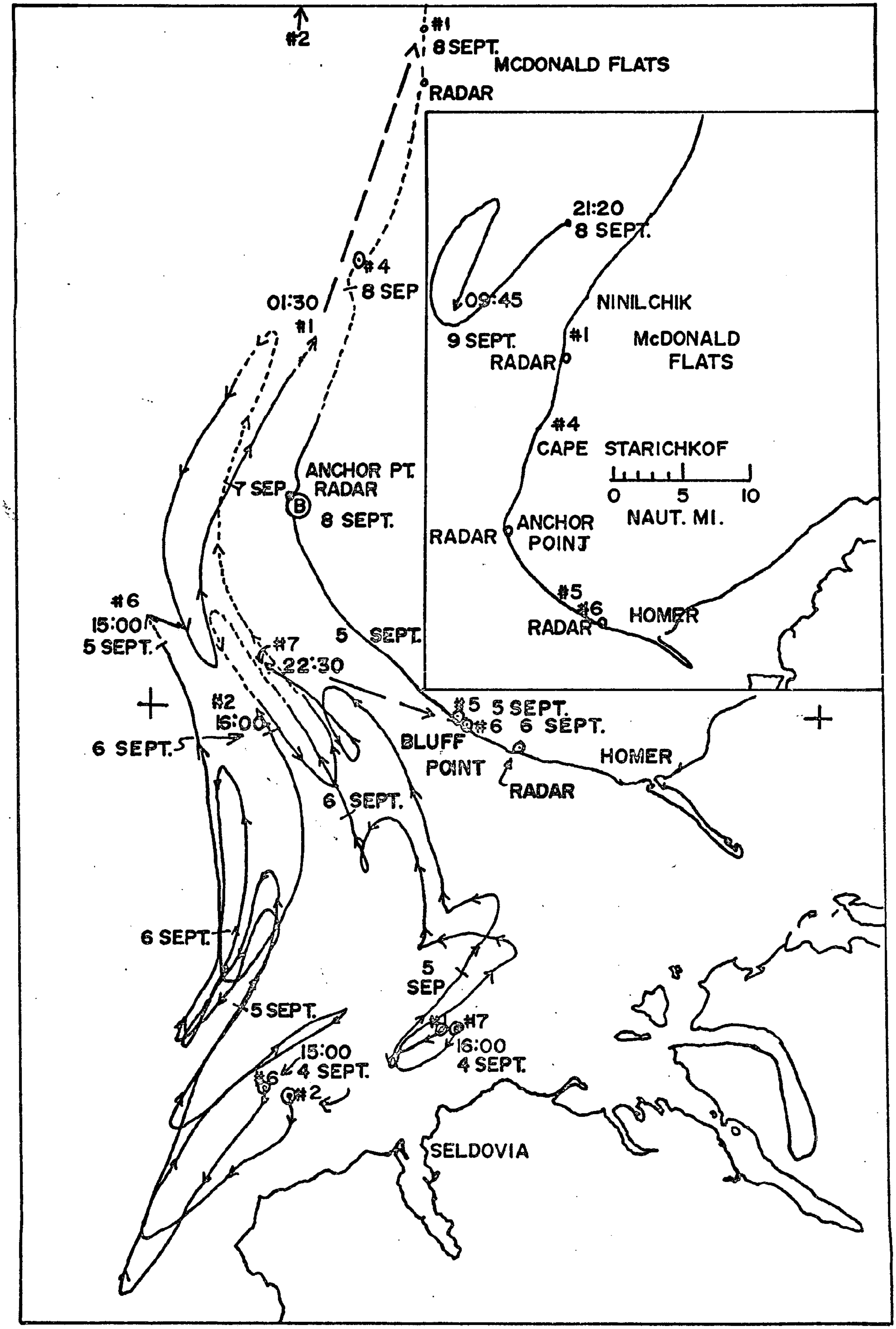


Fig. 17 - Drogue Drift, 4-9 September 1975

Period 10-17 November 1975

Weather during the period 10-17 November was characterized by moderate (approximately 10 kts) westerly to southwesterly winds, interrupted by a period of strong (20-30 kt) westerly to southwesterly winds beginning the evening of 13 November and subsiding early on 15 November. Direct and indirect influence of the wind on drogue assembly drift was probably significant during the entire period of observations, however, weather data for the outer bay have not as yet been fully analyzed.

Drogue trajectories are shown in Figure 18. Southward movement of drogues 8 and 9 suggest the possible existence of a clockwise gyre in the southwestern outer bay, (figure 19), although its size is much smaller than that of clockwise gyres previously ovserved. Within 3-4 nautical miles of the southern shore, an obvious eastward movement of surface and subsurface waters was observed.

In the entrance to the upper bay, the surface water exhibited a predominant NE-SW oscillation (with no significant net movement) in synchronism with the flood and ebb of the tides; the surface drogue (#3) remained in the same vicinity for approximately 7 days before transgressing into the Homer small boat harbor. Water movement at 100 feet differed markedly from the surface movement, as evidenced by a rapid southwestward drift out of the entrance to the bay.

Drogues 1 and 23, released in the northwestern portion of the outer bay reaffirmed a unique differentiation between the surface and subsurface currents observed earlier in the season (4-8 Sept.) during a southwesterly gale of 3 days duration. The strong (20-30 kt) westerly to southwesterly winds which developed a few hours after the release of drogues 1 and 23 drove the surface drogue (#1) rapidly to the north, whereas the subsurface drogue (#23) was carried rapidly east. More definitive explanation of the observed transport must however await further detailed analysis of the records.

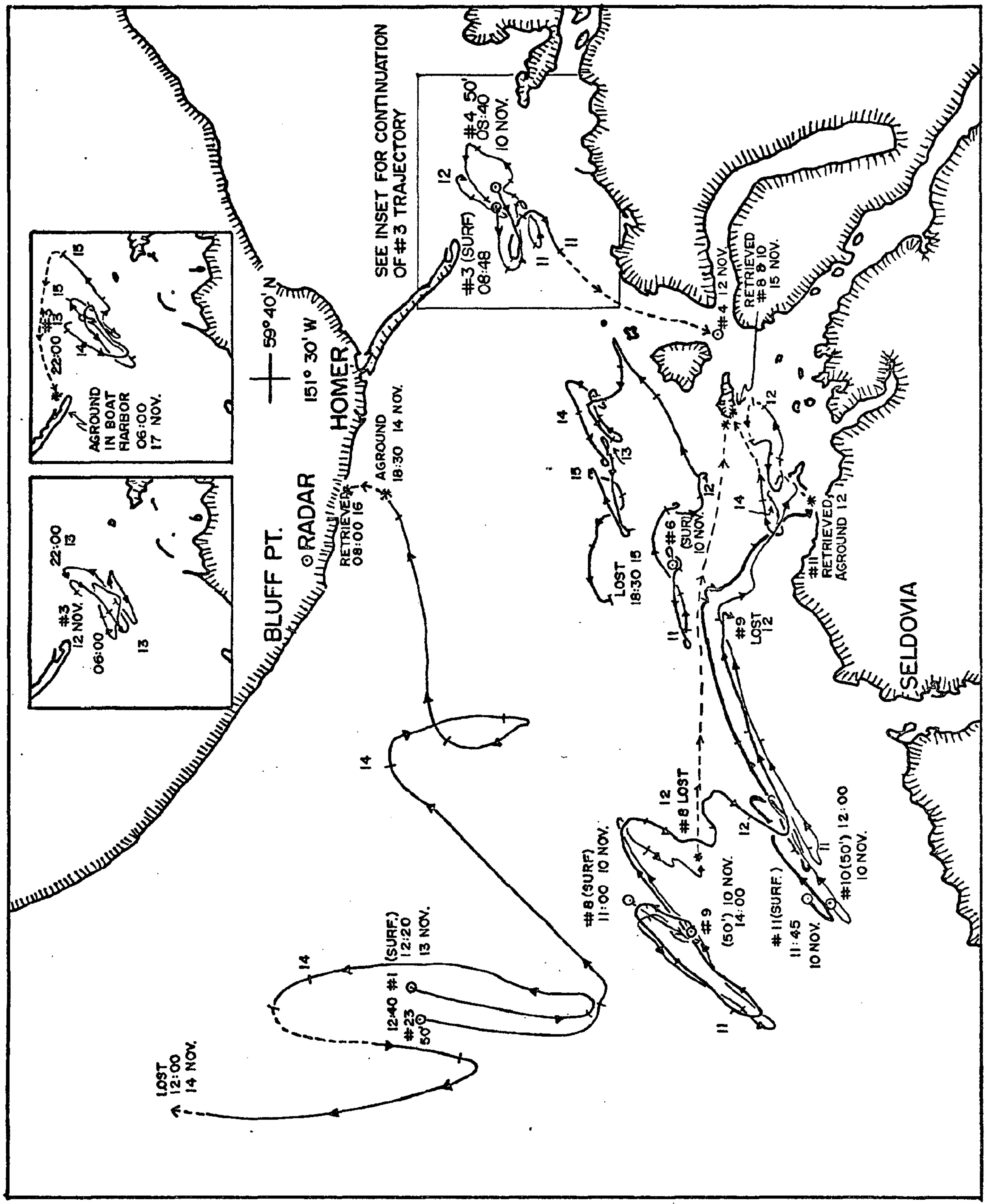


Fig. 18 - Drogue Drift, 10-17 November 1975

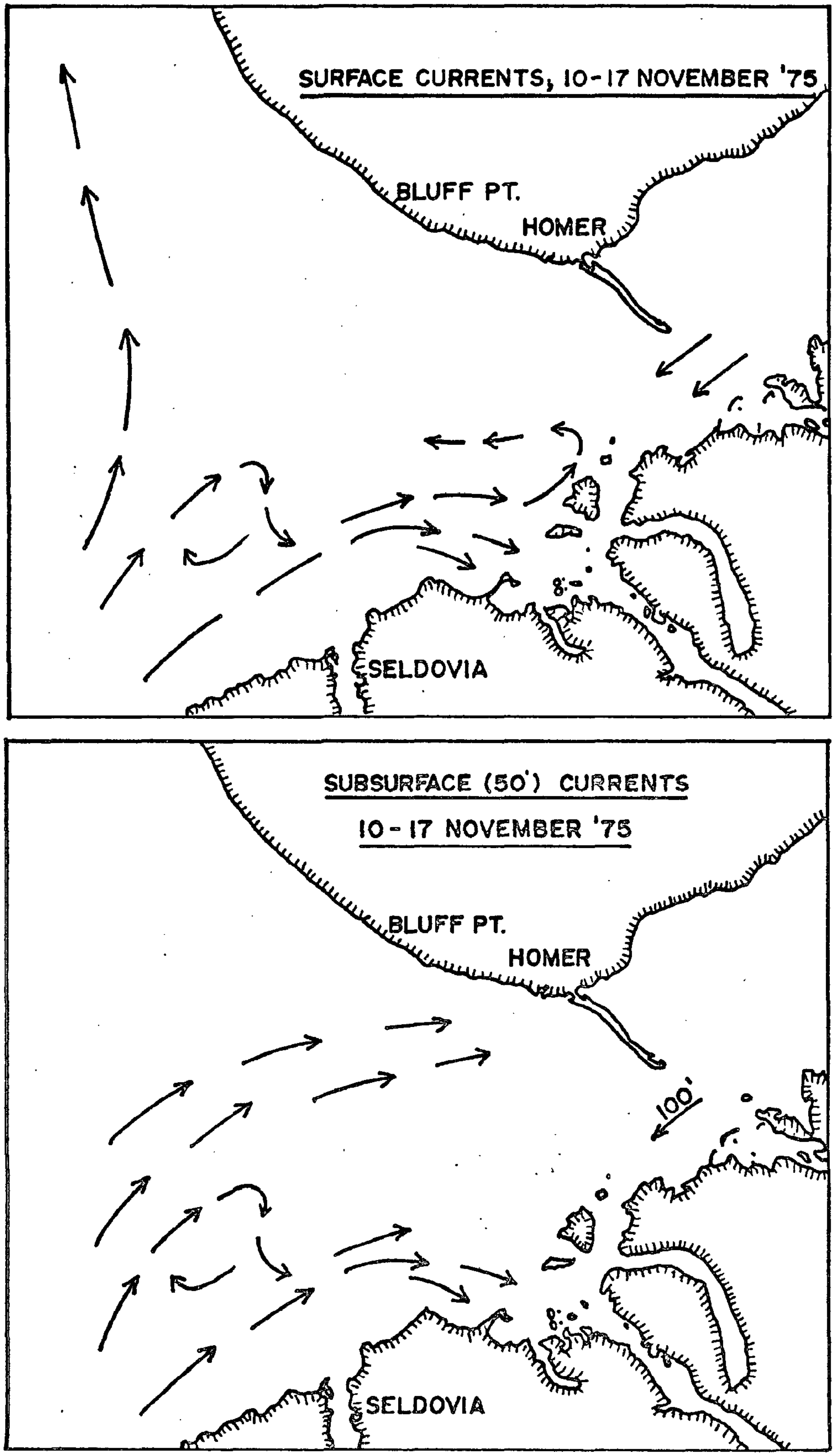


Fig. 19 - Drogue Trajectories, 10-17 November 1975

Period 18-20 November 1975

Weather during this period was characterized by steady 20-30 kt northeasterly winds which abated for a short period on the morning of the 19th (2200, 18 November - 0600, 19 November). Surface and subsurface drogue movements in the upper bay (figure 20) was generally WSW, in the direction of the wind field, until the drogues were within a few miles of Homer Spit, at which time they were carried around the tip of the spit. In addition to the general counterclockwise movement observed in the southwestern region of the upper bay, smaller gyres (1-2 miles in diameter) were observed near the tip of Homer Spit; these consisted of a subsurface (50') counterclockwise gyre on the north side and a surface clockwise gyre on the south side.

Of particular interest is the movement of drogue #10 during the period 0200-0400 on 19 November. Although the tide was ebbing from 0134-0713, drogue movement during the first 2-3 hours of the ebb tide was easterly up bay.

Following this period of calm, northeasterly winds of 10-20 kts prevailed for the duration of the tracking period. The resultant water movement in the outer bay was generally westward and at an unusually high velocity. The waters tended to spread out laterally, with a particularly noticeable northward component along the northern shore. Inferred circulation, based upon drogue movements, is shown in figure .

Wind influence, both direct (wind drag on the above-surface reflector) and indirect (surface water transport induced by wind drag on the water surface), was no doubt significant during most of this period. However, it is difficult to differentiate between the magnitudes of each factor with respect to surface drogue movements. However, a measure of the direct wind influence on the exposed reflector of subsurface (50') drogues was obtained by comparing the drift of a standard 6 foot square canvas biplane (#26) and with that of a personnel parachute (#19) (ratio of cross-sectional areas, approximately 1:12.6 respectively.)

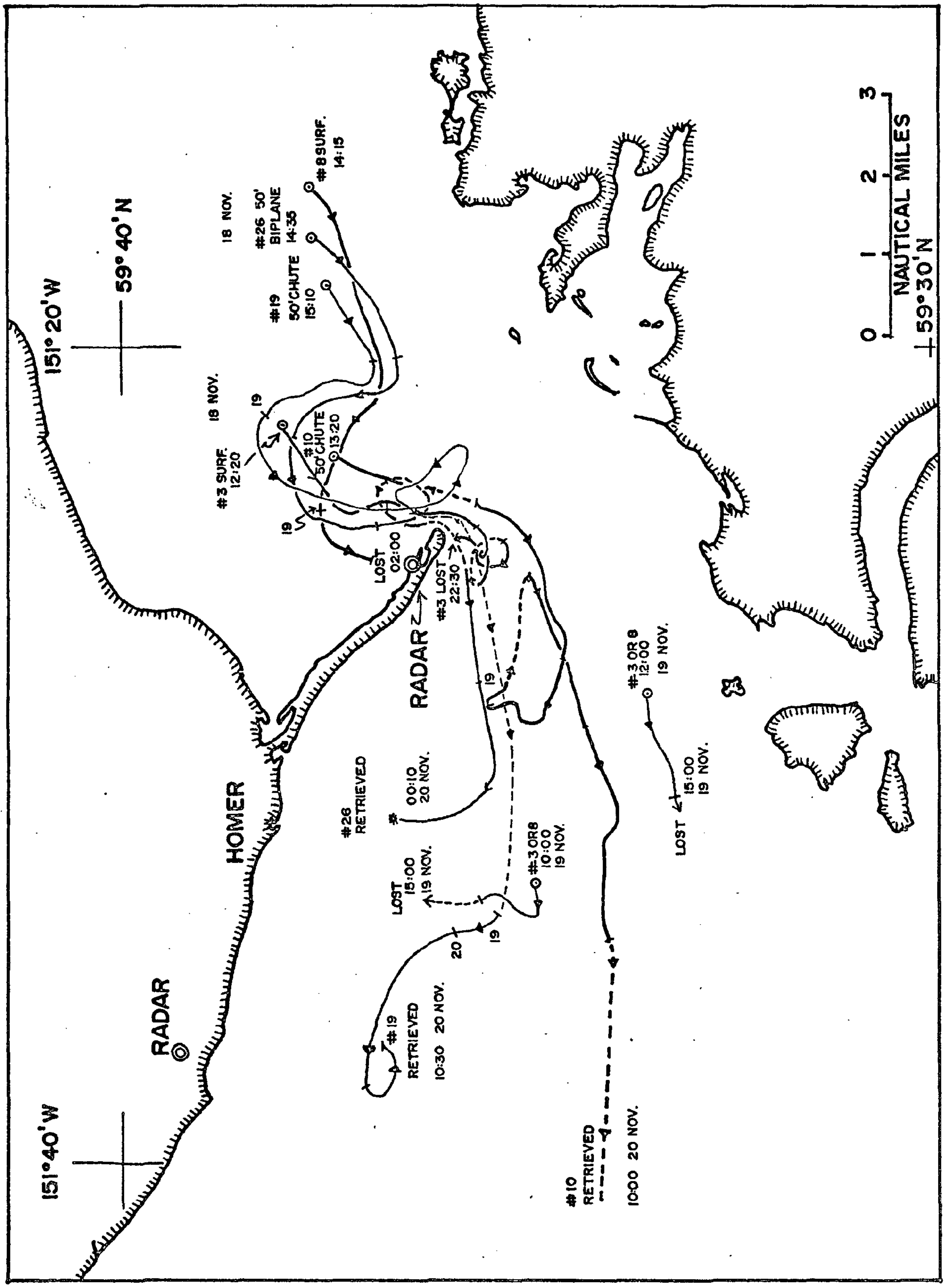


Fig. 20 - Drogue Drift, 18-20 November 1975

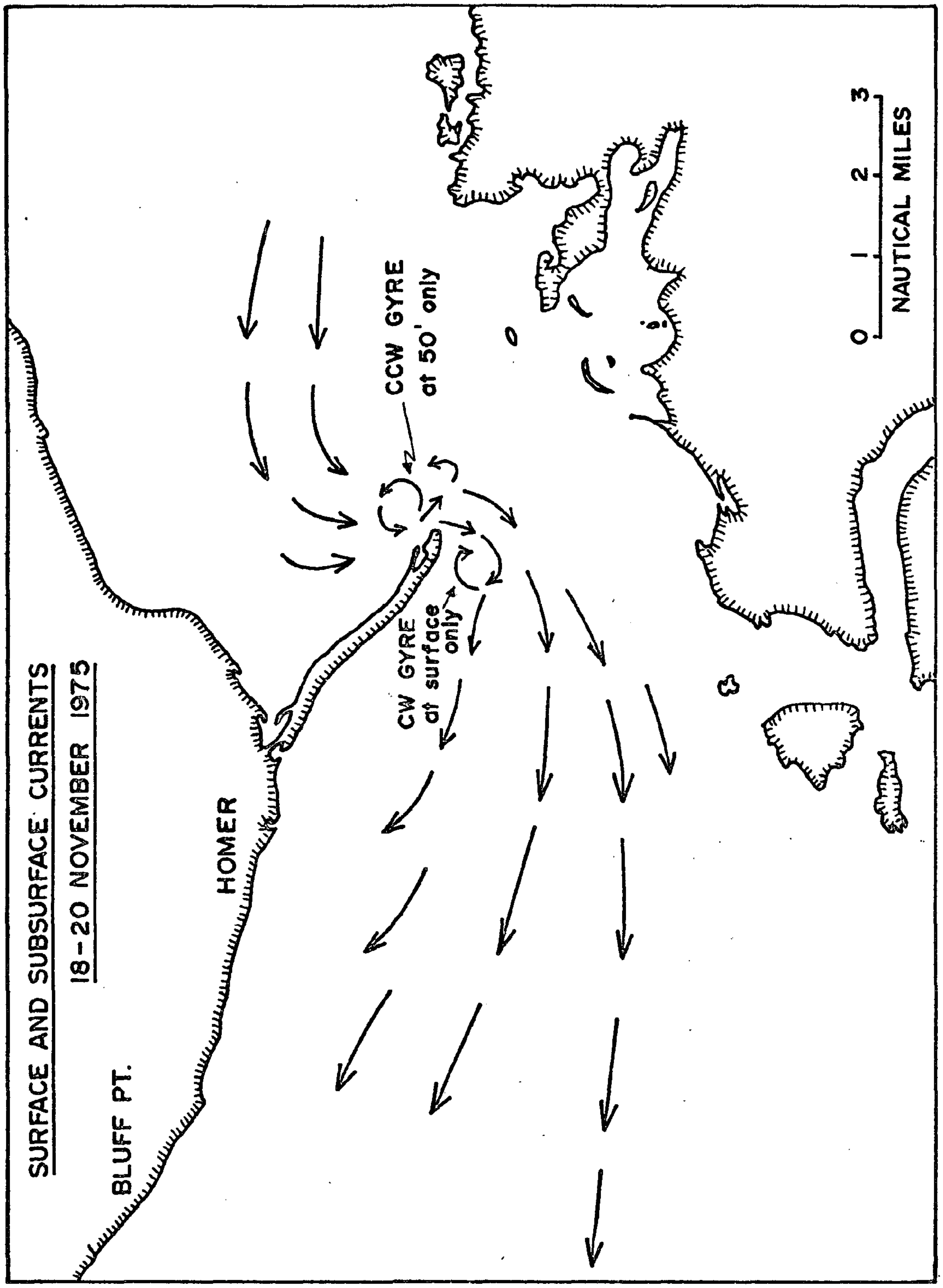


Fig. 21 - Drogue Trajectories, 18-20 November 1975

The results, to date have shown:

1. The stages of the tide during which a given larvae pollutant or object is introduced into the water column plays a controlling role in determining the eventual net trajectory. For example, figure 13 shows the trajectories of two surface drogues which were set adrift at the same position but at different stages of the same tidal cycle. Number 1 was set adrift at 0820 hrs. on 16 July at high tide, while number 4 was set adrift at 1415 hrs., about six hours later, at low tide. Number 4 escaped from the inner gyre and was transported 13 n. mi. farther offshore, to the western edge of the outer gyre. Number 1 remained within the inner gyre, although its pattern of drift suggested that it might also have transected further offshore to the west. Such differences in net transport from a singular geographical position may be even greater in the westernmost reaches of the outer bay, where tidally induced current osciliations of as much as 11 n. mi. in amplitude are observed during each tidal cycle.
2. During the periods of small (neap) tides, effects from non-tidal factors, such as variations in winds and runoff may induce profound perturbations in the circulation regime in the outer bay.
3. In the westernmost reaches of the outer bay, the large amplitudes in tidal current oscilations exert a major control upon dispersal and mixing processes, as shown by the lack and/or weakness of the density stratification in Cook Inlet proper.
4. Present observations strongly suggest that winds have a profound effect on the net circulation of Kachemak Bay and Cook Inlet, and that transient events such as a gale may be most significant in controlling the transport and dispersal of planktonic larvae and pollutants.

Drift Card Studies

Drift cards were released at several locations in an attempt to obtain further insights on long term patterns of dispersals of waterborne components. The general circulation of Cook Inlet is still not well understood, but certain general features appear to dominate the movement and distribution of sea water properties throughout the area. An inferred net surface circulation for Cook Inlet is illustrated in Fig. 22, from the works of Anderson et al (1973) and Wright and Sharma (1973).

The inferred model, based upon water mass characteristics, turbidity and imergency from ERTS Satellites (Burbank 1974), indicate strong influx of saline, relatively clear coastal shelf water along the eastern shore and strong outflow of brackish, turbid water along the western shore.

During August and September of 1974, a total of about 10,100 drift cards were released at selected points in Kachemak Bay and southern Cook Inlet. The results are summarized and illustrated as follows:

Site A (Vessel Holding or Anchoring Area) Figure 23

Recoveries from this site were extrememly good, averaging 15%; Drift cards from this site tended to move rapidly seawards past the end of Homer Spit. The majority of recoveries occured within a week, usually from along the seaward side of Homer Spit (probably one of the most intensively beachcombed area of Cook Inlet). During a persistent period of westerly winds at the time of a drop, significant numbers of cards were carried to the south side of Kachemak Bay, particularly in the China Poot Bay area. No cards released at this site A were reported north of Bluff Point; a single card was recovered from Amakdedori Beach directly west across the Inlet from Kachemak Bay, two months after the drop. The finding of this card, on the Kamishak side of the inlet is in close agreement with the observations of local mariners who suggest that objects adrift in upper Kachemak Bay tend to come ashore either in the vicinity of the Spit or on the Amakdedori Beach side.

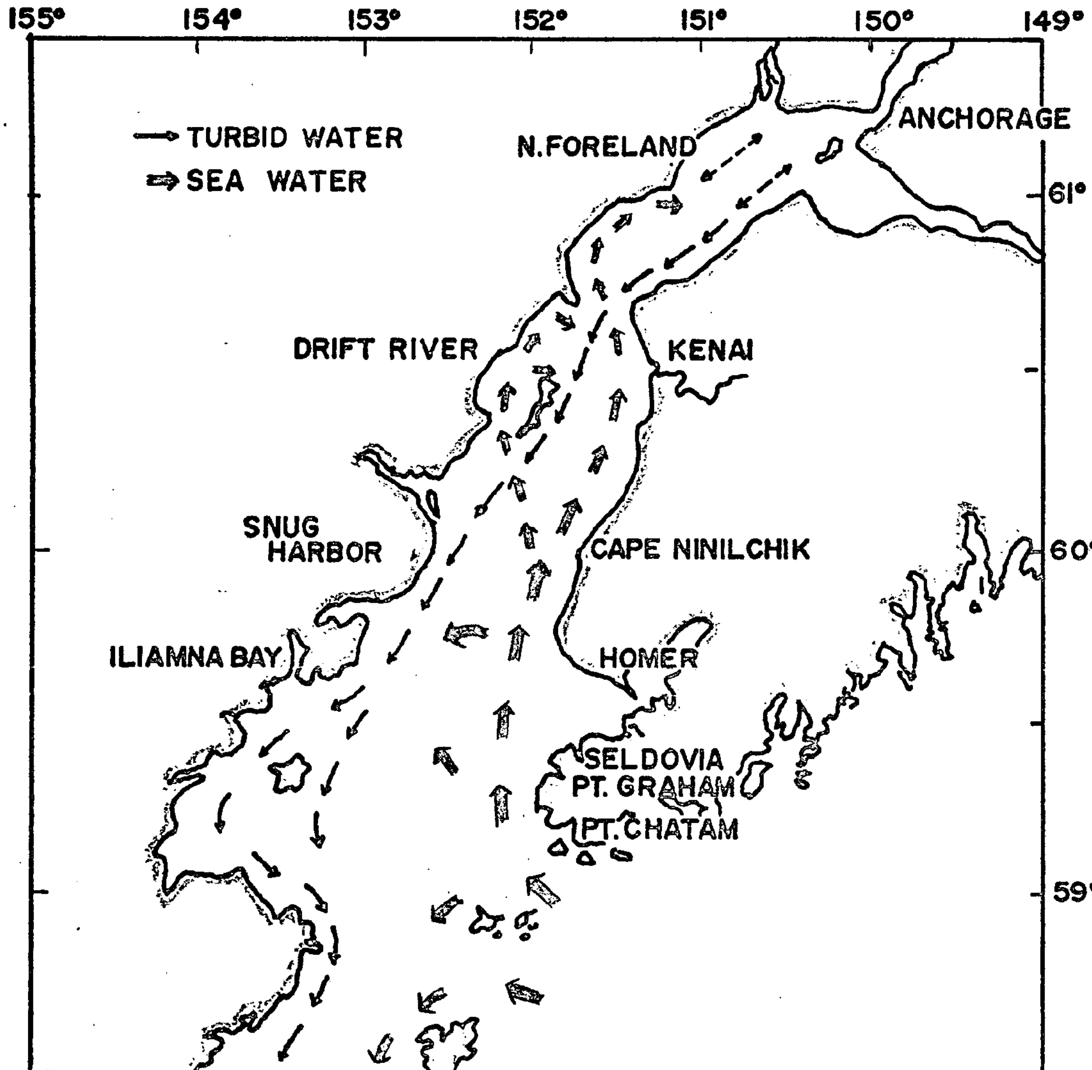
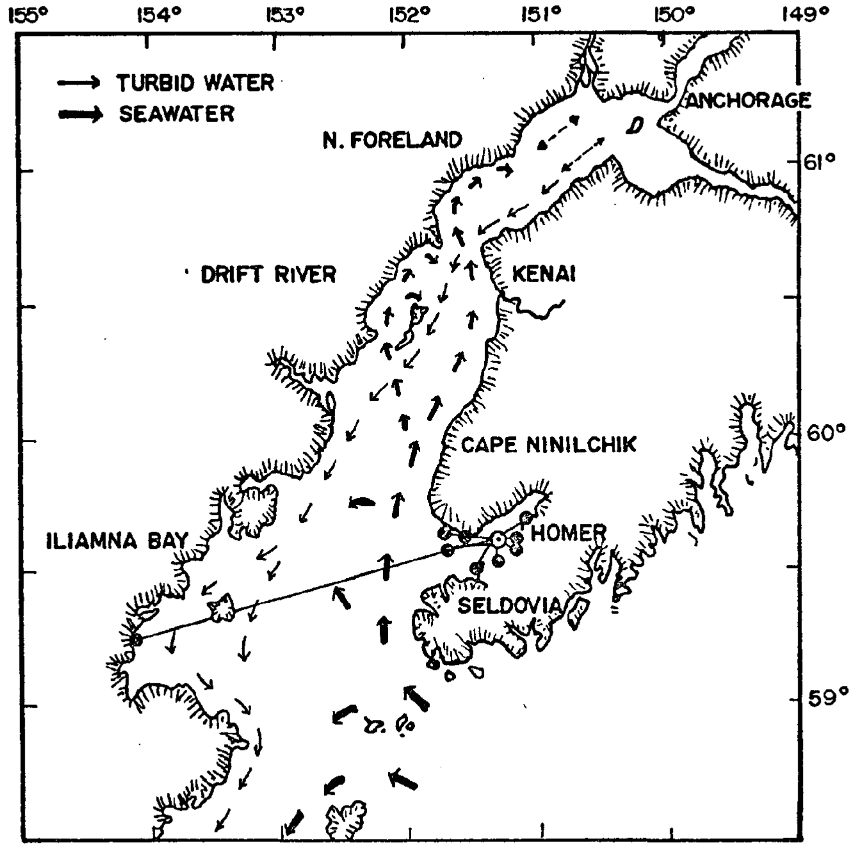


Fig. 22 - INFERRED NET CIRCULATION - COOK INLET

(From Burbank, 1974).



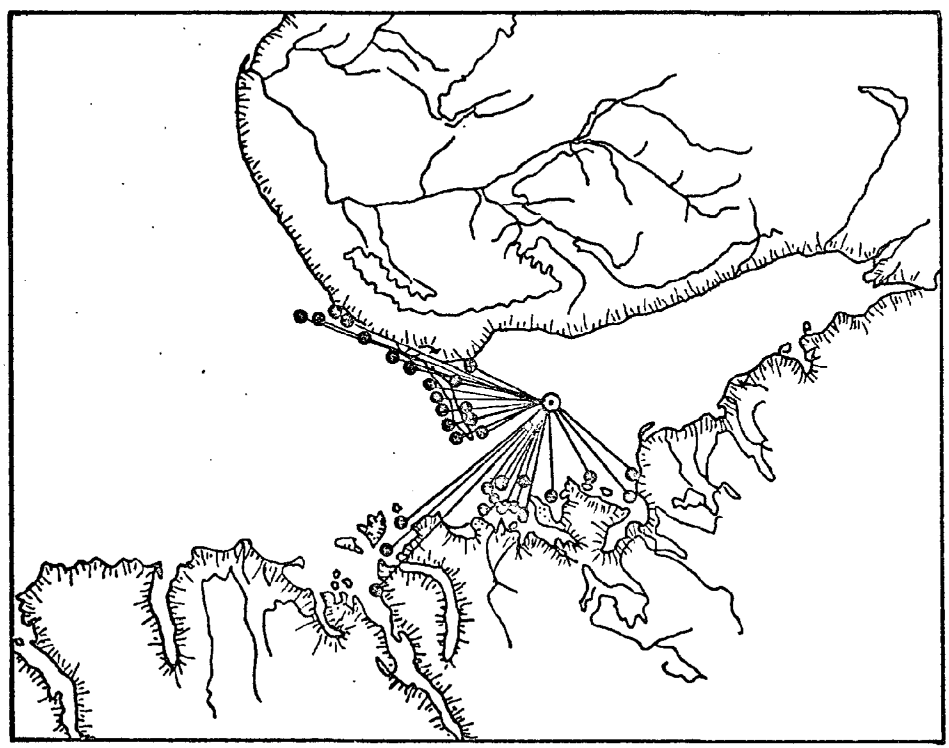


Fig. 23 - Drift Card Recoveries - Site A
(Vessels Holding and Anchoring Area)

Site B (Homer Spit) Figure 24

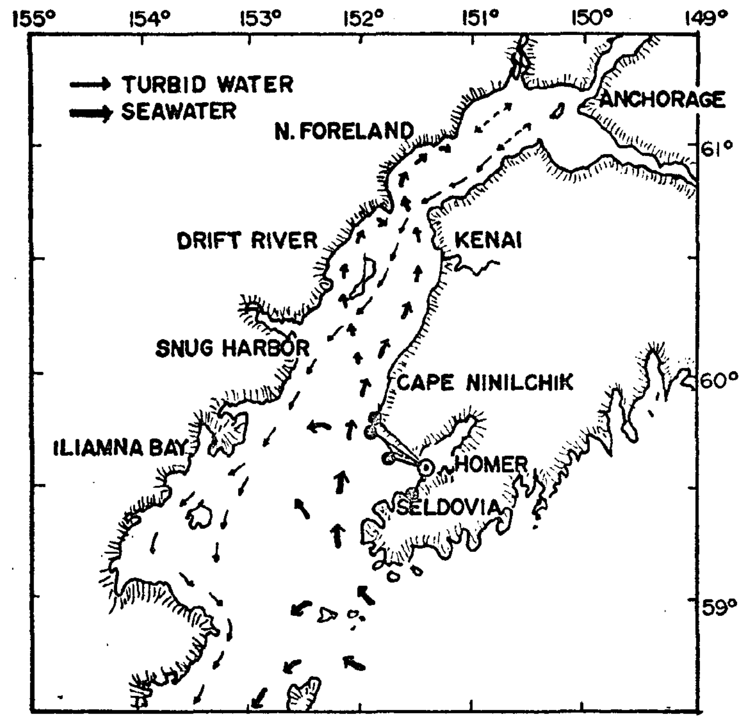
To correlate the information from Site A, cards were released at the end of Homer Spit. Returns were much poorer than from Site A, averaging 3.5%, but the pattern was quite similar. Most recoveries were on the Spit or from the Northwest shore towards Anchor Point. One card was recovered from Eldred Passage on the south shore of Kachemak Bay.

Site C (Yukon Island) Figure 24

This site, one mile north of Yukon Island, was selected to characterize water movements along the south side of Kachemak Bay. It was anticipated that drift would be rapid, to the northeast into the upper bay. This apparently did not happen, for returns were poor (averaging 1.1%), and entirely from the north, along the Kenai Peninsula, or west in Kamishak Bay.

Site D (Point Pogibshi) Figure 25

It was anticipated that drift of cards released off Pt. Pogibshi could either move directly north toward Anchor Point or ENE along the southern shore of Kachemak Bay. Returns from this station were adequate, averaging 2.2% for five separate drops, and definitely indicate that waters from Point Pogibshi follow both routes. On one occasion, August 11, cards were recovered from Homer Spit within a week and at Kalgin Island within two weeks from the time of release.



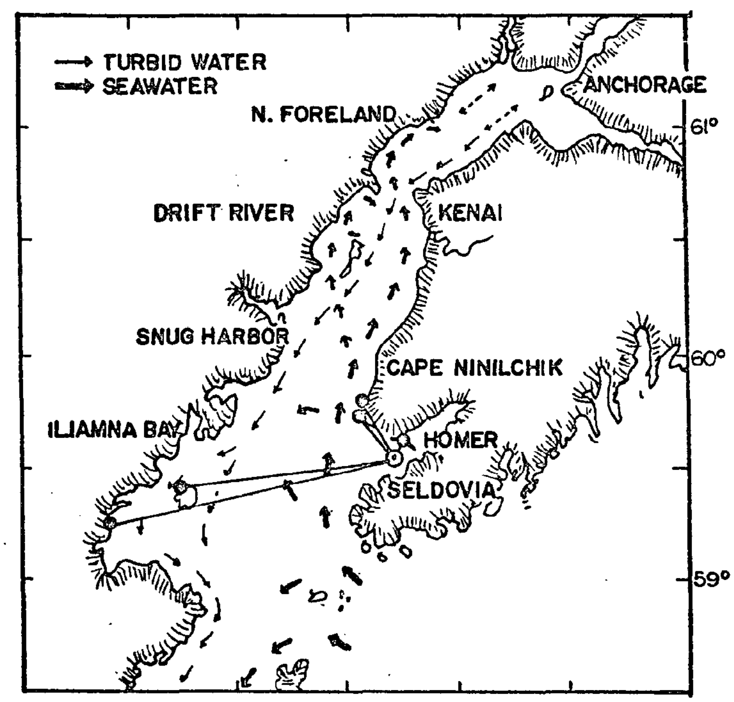
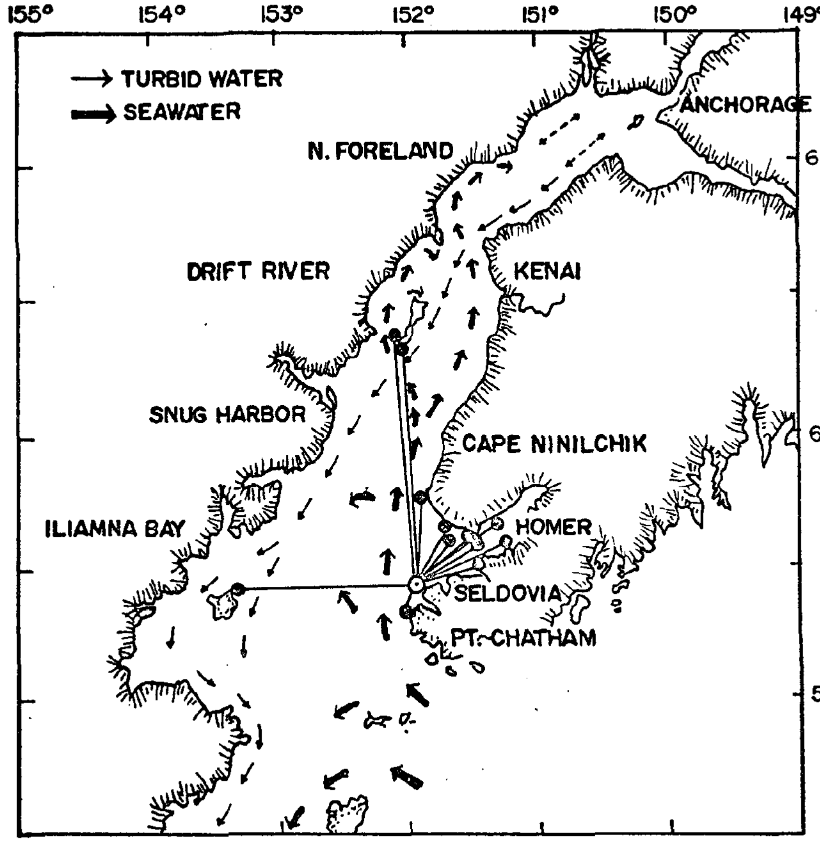


Fig. 24 — Drift Card Recoveries
Site B (Homer Spit)
Site C (Yukon Island)



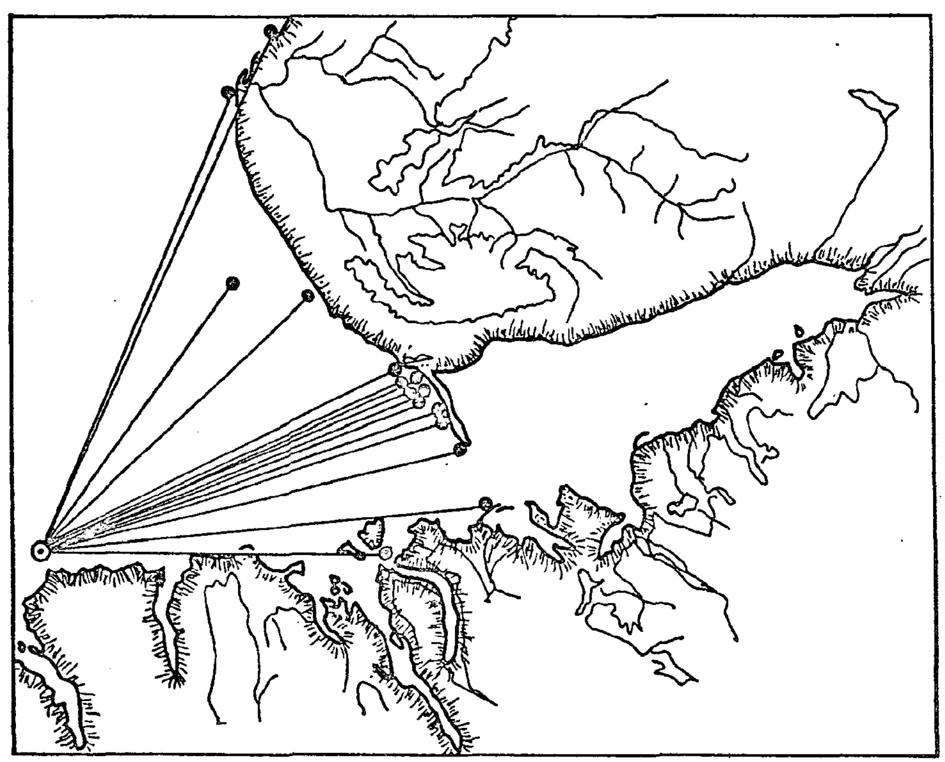


Fig. 25 - Drift Card Recoveries - Site D
(Point Pogibshi)

Site E (Shell, SoCal Exploratory Drill Site) Figure 26

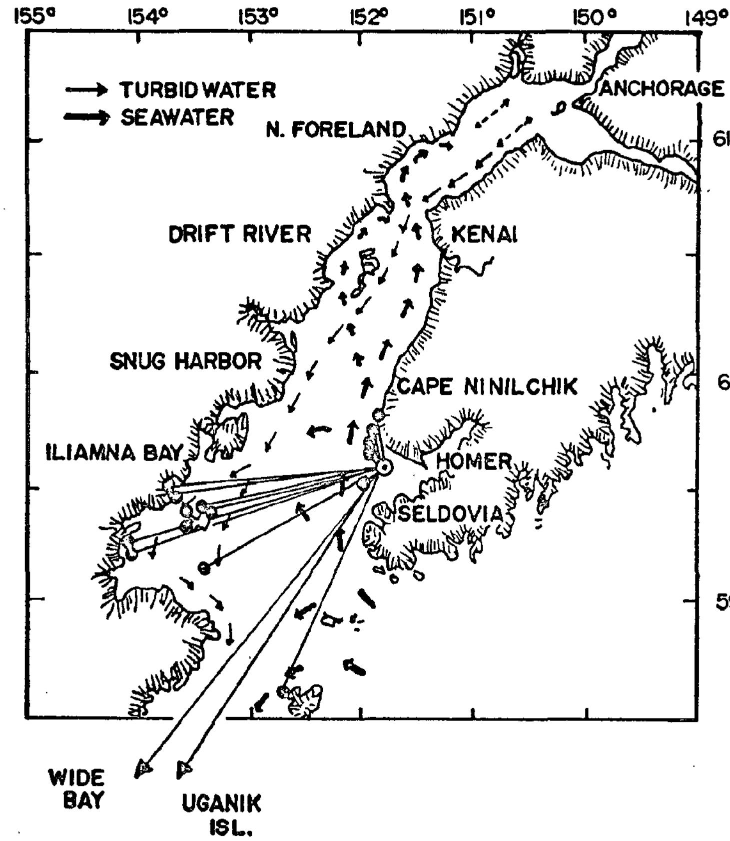
The proposed Shell Oil drilling site in the middle of outer Kachemak Bay was regarded as particularly important, for it was believed to lie in the center of a crusteacean nursery area. Over 3000 cards were released here upon six different occasions, but returns were porr, averaging less than 1%. Recoveries were recorded from Anchor Point, Augustine Island, Kamishak Bay, and several of the most distant discovery points along Shelikof Strait. One card was returned from Wide Bay on the Alaska Peninsula west on the north shore of Shelikof Strait, the most distant authenticated return to date. This card must have traveled at least 250 and more likely 350 nautical miles in less than 2-1/2 months.

Sites F & G (Bluff Point - Anchor Point) Figures 26, 27

Returns from these two sites averaged only less than 1%. On three separate occasions no cards were recovered. Site F (midway between Bluff Point and Site E had returns only from Anchor Point and from Augustine Island. From Site G (1.5 miles west of Anchor Point), cards were returned from near Bluff Point (to the east, possibly a result of drift along the beach), from the Anchor Point-Cape Starichkof shore nearby, and from Spiridon Bay, on the Kodiak Island side of Shelikof Strait.

Site H (Cape Kasilof - SoCal Exploratory Drill Site) Figure 27

This release point was located almost 50 miles north of Kachemak Bay, one nautical mile NW of the Sisters, off Cape Kasilof, the site of a Standard Oil of California exploratory well. Recoveries from this site were about average, 2.8%. A high recovery of 8.7% occurred on one occasion during a period of persistent onshore (WNW) wind, the only significant card recoveries from the Kenai Peninsula shore. In general the drift cards



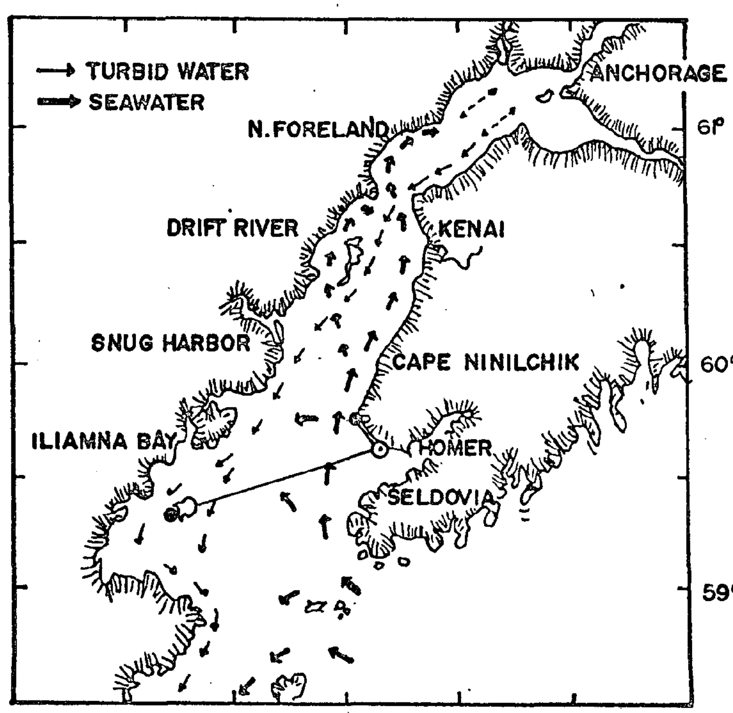


Fig. 26 - Drift Card Recoveries
Site E (Shell, SoCal Drill Site)
Site F (Bluff Point)

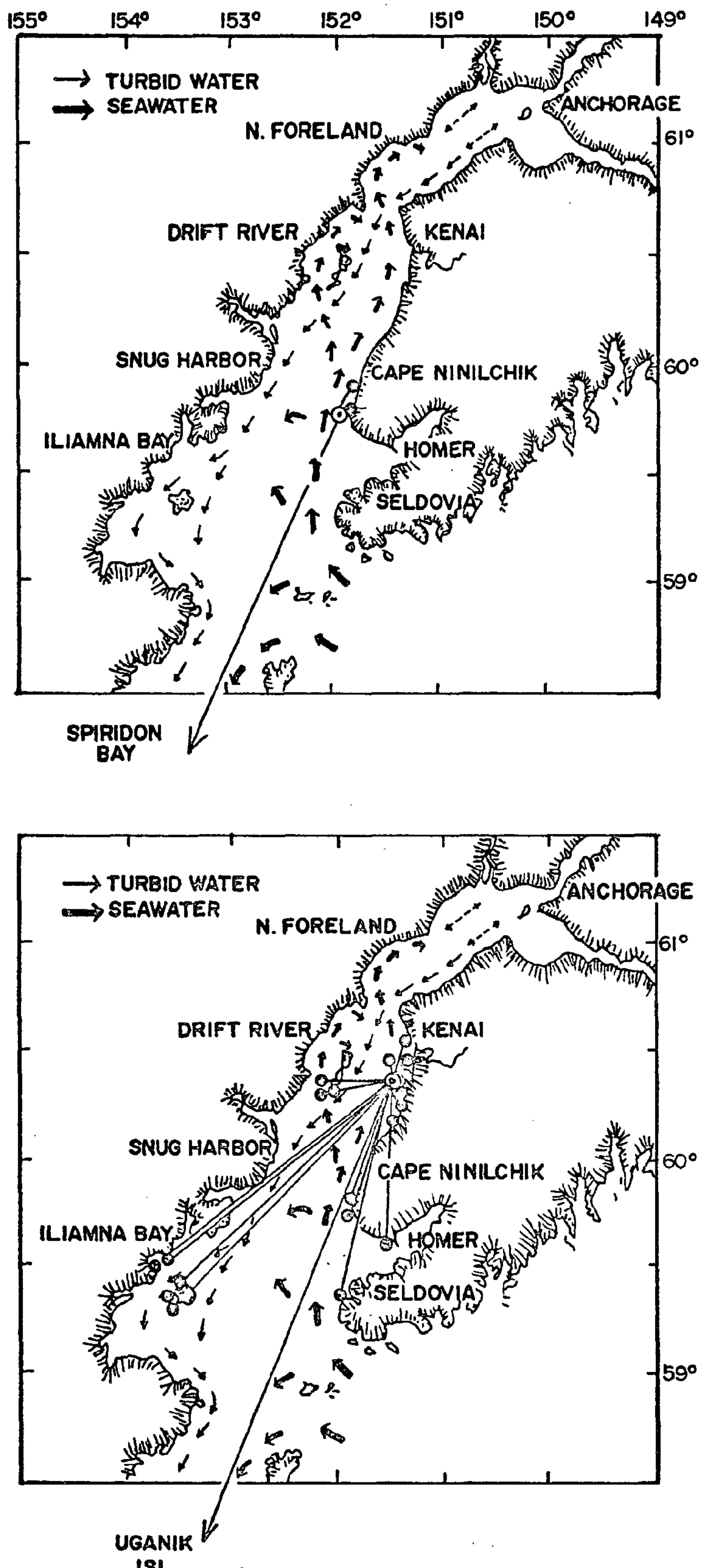


Fig. 27 - Drift Card Recoveries
Site G (Anchor Point)
Site H (Cape Kasilof - SoCal Drill Site)

released off Cape Kasilof were recovered at Kalgin Island or along the west side of the Inlet. There were recoveries from Ursus Cove, Augustine Island, and a single card from Uganik Island, south of Shelikof Strait.

Seasonal Properties of Kachemak Bay Marine Waters

The marine waters of Kachemak Bay exhibits marked seasonal variations in temperature, salinity, density and oxygen distribution. The seasonality of water mass properties can best be described from the work of Knull and Williamson (1969) and from the earlier studies of Bright et al (1960).

Present information shows that the water temperatures of the bay respond to both seasonal as well as year to year variations in warming and cooling processes, as illustrated in figure 28. Of interest are the low temperatures recorded for the winter and early spring of 1959.

As previously mentioned, Kachemak Bay receives the greatest portion of the drainage from the surrounding mountainous area thus the yearly regime of the runoff controls much of the estuarine properties of the bay. Figure 29 illustrates the seasonality of influx of fresh water into the bay.

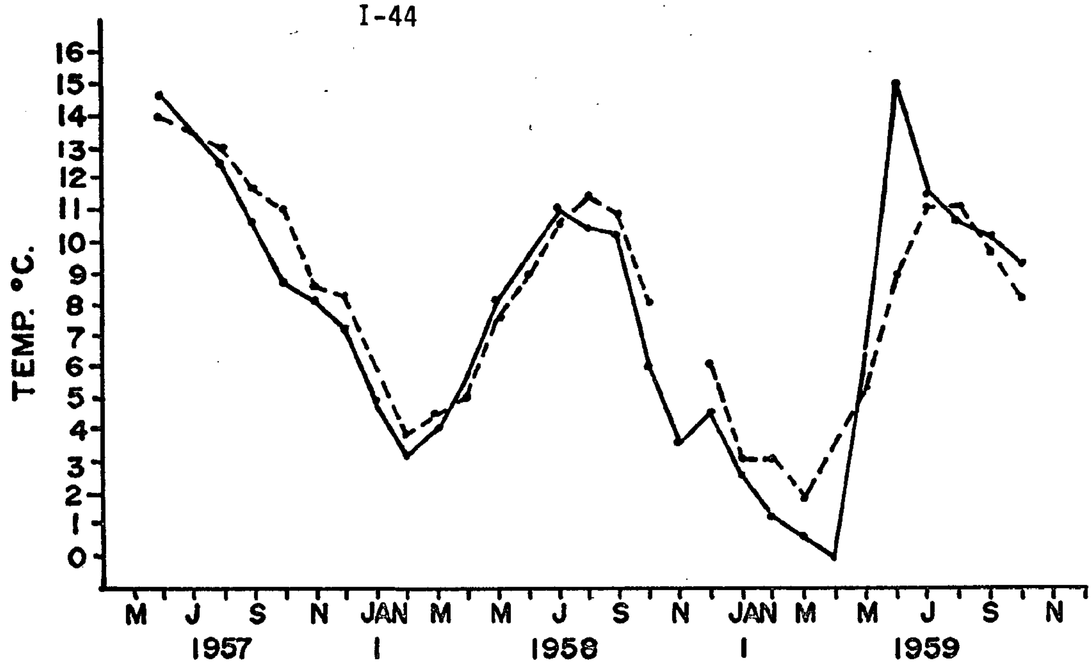
The seasonal regime of sea water properties can be summarized as follows:

1. Late Winter - Early Spring

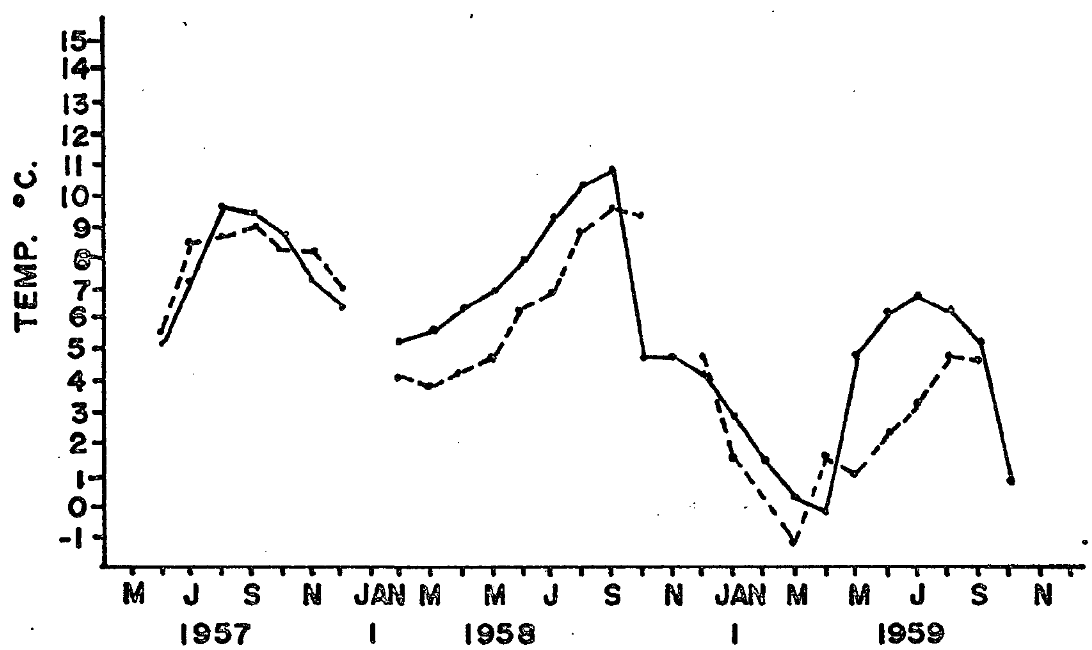
The "oceanographic winter", characterized mostly by low water temperatures, occurs between February and April. Salinities usually remain fairly high and stable, at about 32‰. Prior to breakup, in February and March, the entire bay is relatively well mixed, as reflected by a near uniform dissolved oxygen content of about 9 ml/l.

The onset of breakup brings about increased influx of fresh water, which, coupled with the warming trend, develops a marked density stratification, making the bay a more typical two layered positive estuary.

The interplay between warming of surface layers, and mixing processes results in the build up of a rather complex density structure as illustrated in Figure 30. The basic density structure can be subdivided into:



MEAN MONTHLY SURFACE TEMP. FOR KACHEMAK BAY



MEAN MONTHLY BOTTOM TEMP. FOR KACHEMAK BAY

Fig. 28 - SEASONAL TEMPERATURE REGIME
(BRIGHT ET AL 1969)

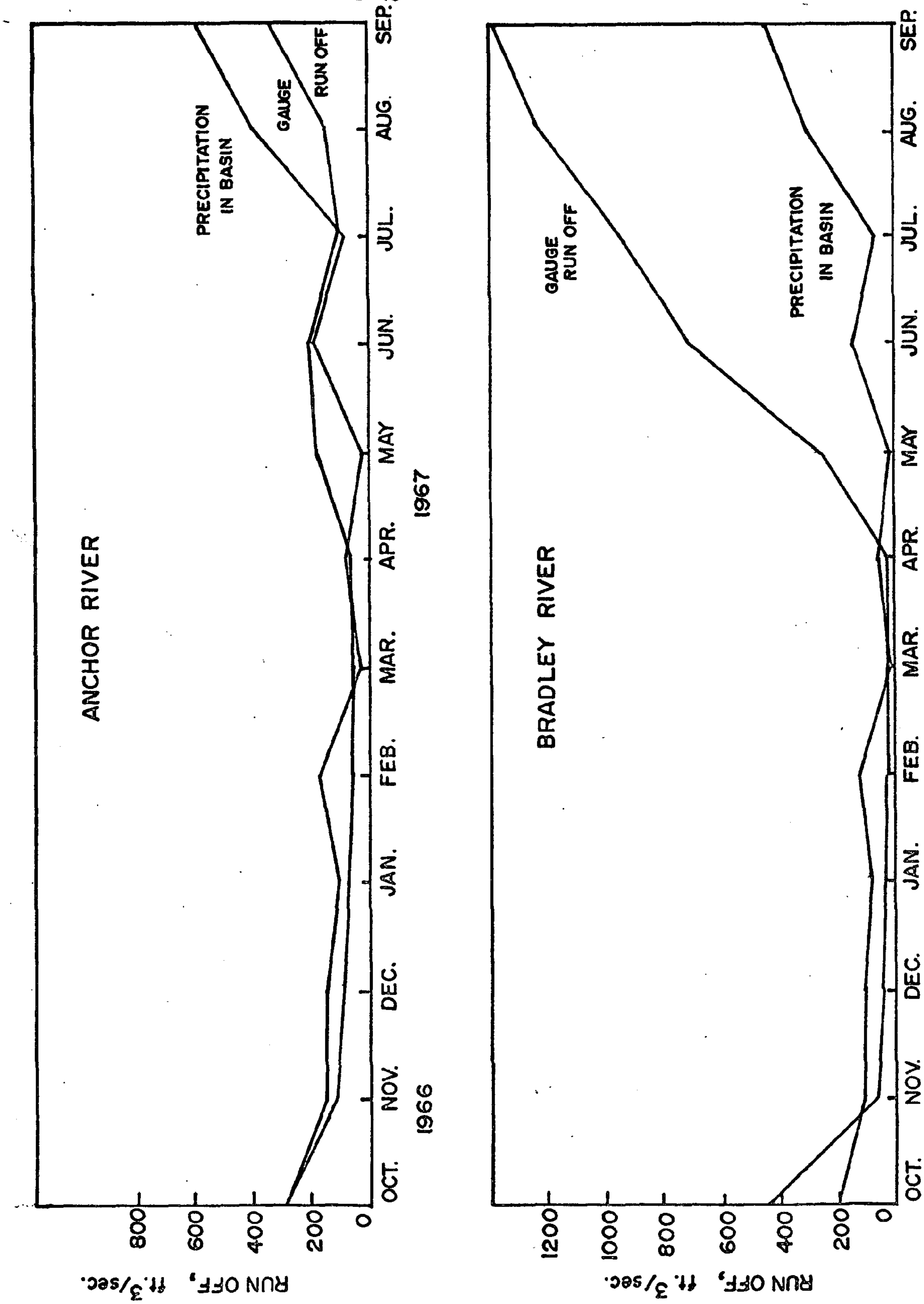


Fig. 29 - Seasonal Run Off Regime For Selected Drainage
(Knull 1969)

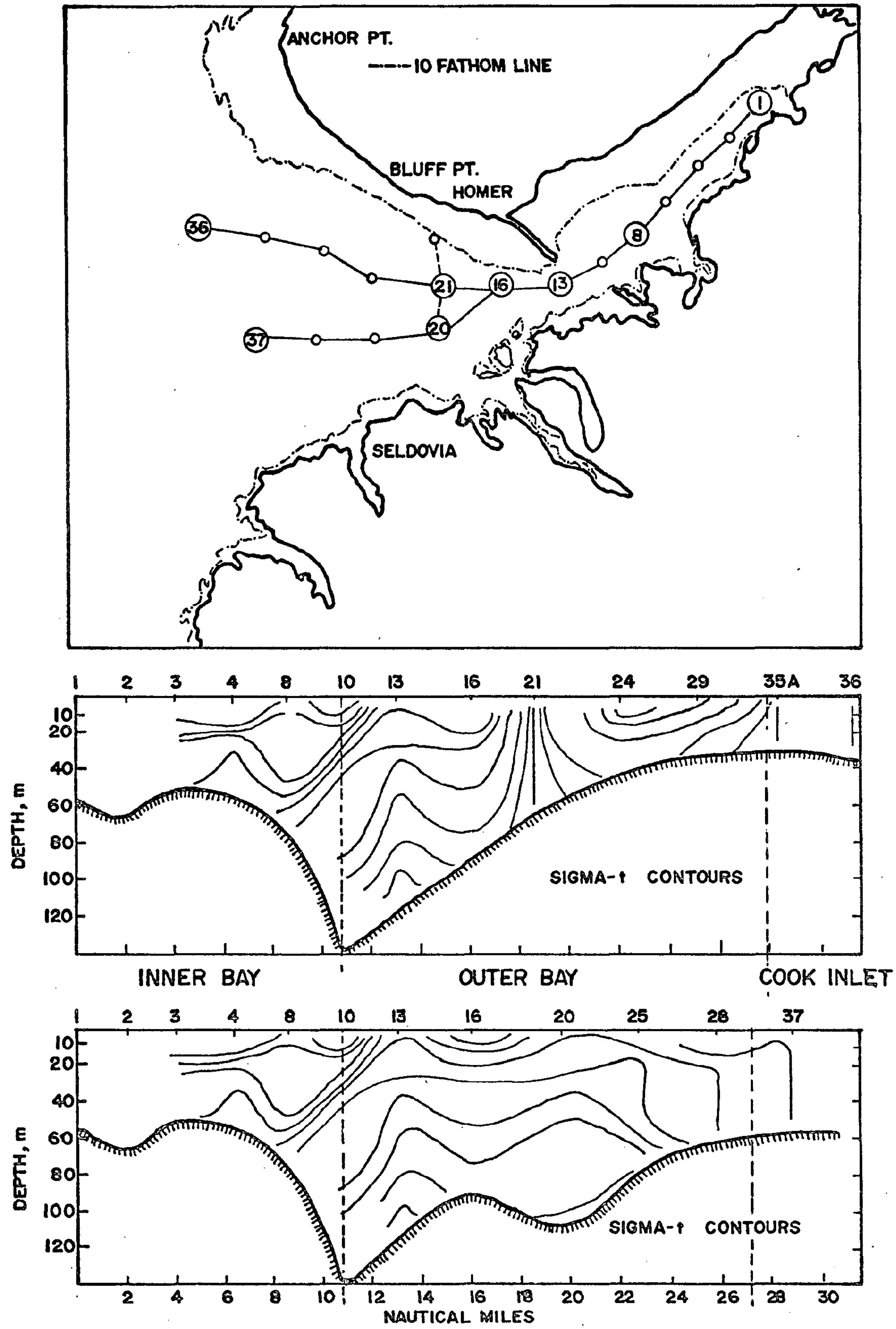


Fig. 30 - Longitudinal Density Stratification - April 1969
(Knull and Williamson - 1969)

a. The inner bay, with its well defined two layer "wedge".

b. The outer bay, with a more complex but still well defined two layer system.

c. Cook Inlet with its typically more uniformly top to bottom mixed water column.

The cross channel density distribution (figure 31) reflects the control of the Coriolis force forging the net outflow of the less saline waters to flow to the right against the northern shore, and the inflow of more saline waters to flow along the southern shore. The density distribution clearly shows that Kachemak Bay becomes a typical two layered positive estuary as soon as breakup sets in.

2. <u>Late Spring to Early Fall</u>

As warming progresses, the fresh water influx into the bay increases and, combined with the increase in surface heating, induces the formation of a well developed thermocline. The net result is the build up of a well developed shallow density stratification; in July, sharp density gradients are usually found between 5 and 10 m. (15-30 ft.) in the inner bay, deepening to 10-20 m. (30-60 ft.) in the outer bay. An example of the well developed two layer density structure of the bay is shown in figure 32. Of interest is the relationship of the density structure of Kachemak Bay to that of Cook Inlet. Figure 33 illustrates what can be considered as a representative conditions for July. The main channel of Cook Inlet exhibits no horizonal stratification, as a result of intense mostly tidally induced mixing; the brackish outflow of Kachemak Bay, combined with the discharge from the Anchor River contributes to the shallow stratified cell observed along the eastern shore.

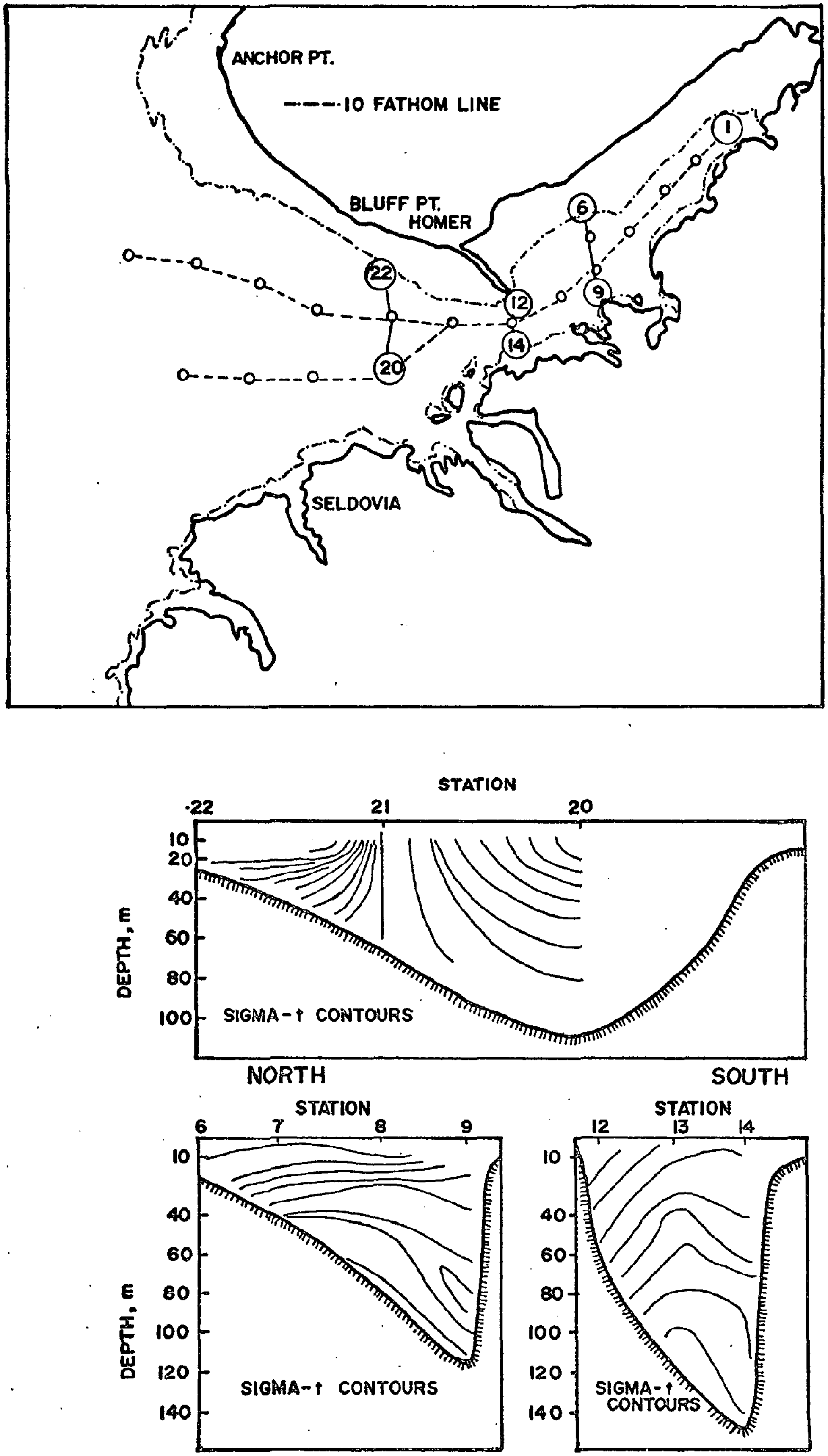


Fig. 31 - Cross Channel Density Stratification - April 1969
(Knull and Williamson - 1969)

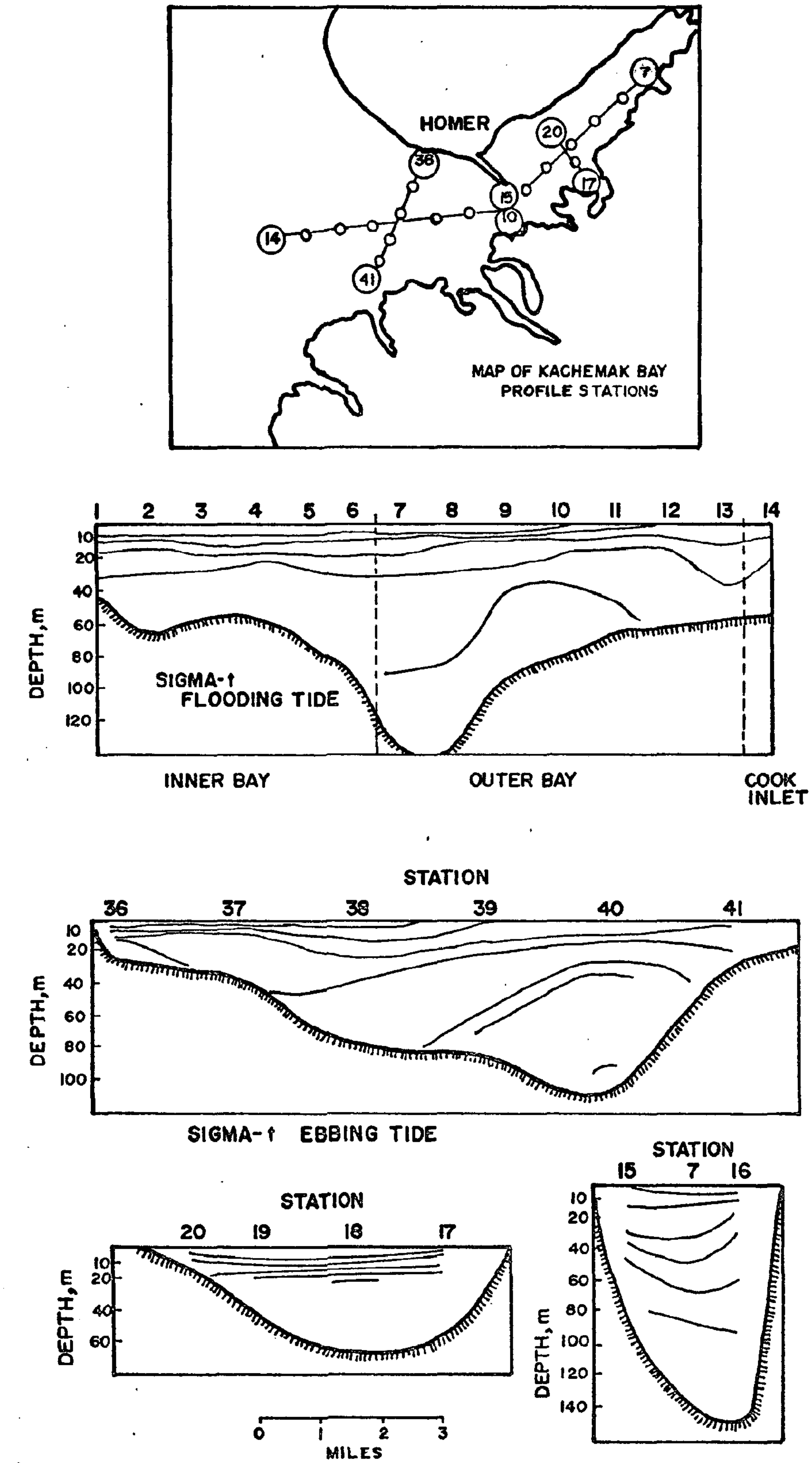


Fig. 32 - Longitudinal and Cross Channel Distribution of Density - July 1969 (Knull and Williamson - 1969)

As expected, the greatest vertical gradients in temperature correlate with the periods of sharpest vertical density stratification. Data from Knull (1969) show that temperature will vary from about 12°c at the surface to 6°c at the bottom of the thermocline (at about 15 m.). Similarly, salinities in the inner bay will vary from about 25-28% at the surface to 31-31.5% at the bottom of the thermocline or a change of about 10 salinity units within 10-15 m. Salinities in the deeper waters are more uniform, ranging between 31.5 and 31.8% throughout the bay. Dissolved oxygen concentrations also reflect the patterns of density stratification, ranging from about 6 ml/l at the surface to about 8 ml/l in the deeper waters.

3. Late Fall and Early Winter

By October, surface cooling wind and tidal mixing and reduction in runoff considerably weakens the sharpness of the density stratification. A temperature inversion develops, the upper, slightly less saline waters becoming colder (less than 8°c as observed by Knull in 1969), the deeper more saline waters being warmer (above 8.5°c). While no data are presently available for winter temperature distribution in the bay, it can be assumed that the temperature inversion, colder water at the surface, warmer waters at depth, will prevail through much of the period between freezing and thawing. (Figure 34)

Convective cooling has been observed at a number of inshore locations of the Gulf of Alaska coast, and it can be postulated at this time that extensive surface cooling during cold snaps will induce convective mixing of the shallower waters of the inner bay. Such convective mixing will contribute to the oxygenation of the entire bay.

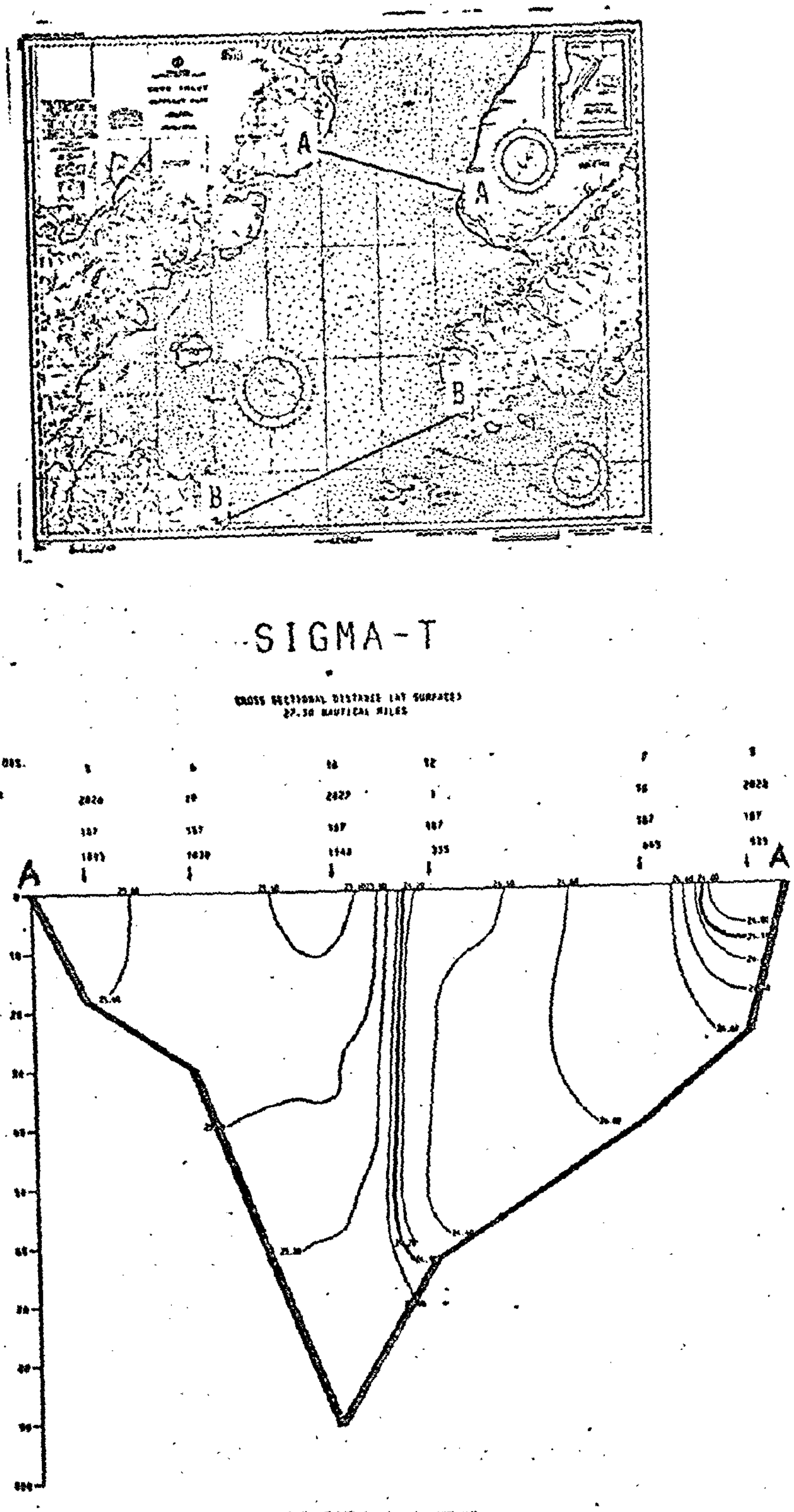
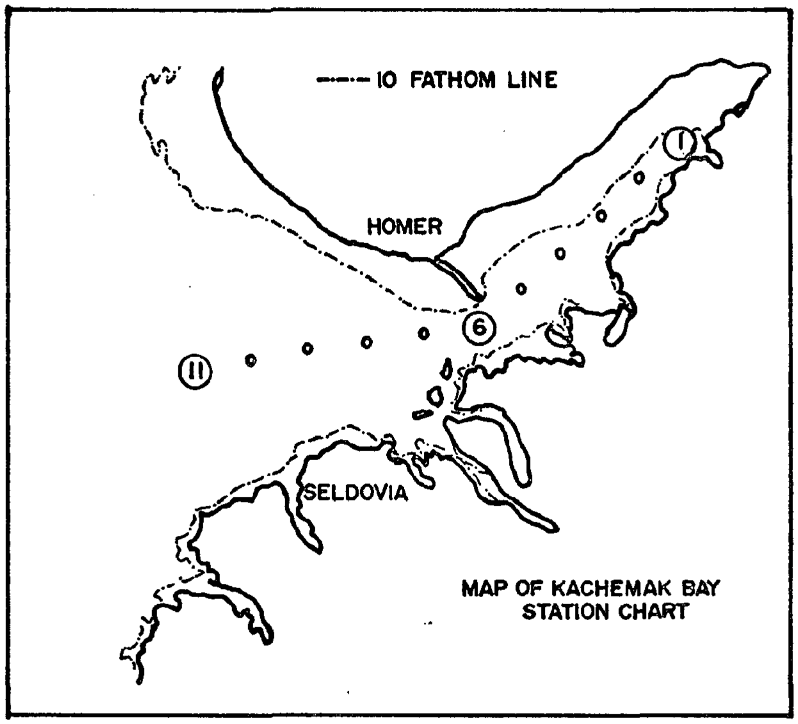


Fig. 33 - Cross Channel Distribution of Density, Lower Cook Inlet July 1973. (NOOA/NOS 1973)



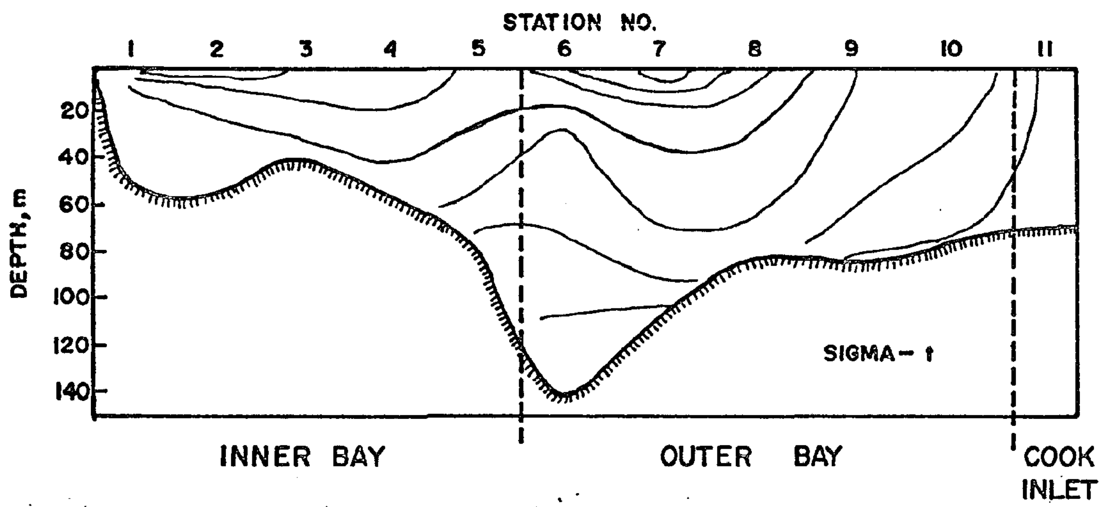


Fig. 34 - Longitudinal Distribution of Density - October 1969
(Knull and Williamson - 1969)

SECTION II

ENVIRONMENTAL AND BIOLOGICAL ATTRIBUTES

OF

KACHEMAK BAY

SECTION II

ENVIRONMENTAL AND BIOLOGICAL ATTRIBUTES

of

KACHEMAK BAY

One of the first approach to gauge the biological importance of an area is usually to look at some fisheries statistics. To put it in perspective, Kachemak Bay comprises only 2.6% of the marine waters of Cook Inlet, yet yields 62% of the shellfish harvest, and, it undoubtedly harbors important life stages of shellfish ultimately harvested in other areas outside the bay.

In 1973 the total salmon harvest in the Kachemak Bay was 126,407 fish. The king crab catch for 1973 was 2.1 million pounds, tanner crab 3.8 million pounds, shrimp 5.0 million pounds, and dungeness crab 300,000 pounds. 407,500 pounds of herring were also taken in 1973 in the Kachemak Bay area. The estimated value of these catches of salmon to fishermen was $200,000; first wholesale value was $400,000. The king crab value to fishermen was $1.7 million; first wholesale value being $3.3 million. Tanner crab value to fishermen was $700,000; first wholesale value $1.7 million. Shrimp value to fishermen was $400,000; first wholesale $1.5 million. Dungeness crab value to fishermen was $200,000; first wholesale value $400,000. Herring value to fishermen was $30,000; first wholesale value $60,000. The total value of the 1973 Kachemak Bay commercial fisheries harvest, as mentioned earler, was $3.2 million to fishermen and $7.3 million first wholesale value.

The Bluff Point Sanctuary was established by the Board of Fish and Game in 1970 to prohibit king crab fishing during a critical part of their life cycle when breeding, moulting and egg hatching occur. This Sanctuary has been closed each year from the middle of January until the end of the king crab season. ADF&G and National Marine Fisheries studies have shown that this area is also a very critical area for not only the adult, but also the juvenile and larval forms.

While the fisheries statistics for the Kachemak Bay area are an eloquant expression of its productivity and values, they only express a partial insight upon the total biological attributes of an area. Also, while statistics might relate to number of fish and poundage of crustaceans, expressing the number of pounds of crabs or shrimps does not provide for a meaningful concept of their abundance.

To better express the combined environmental - biological attributes and values of Kachemak Bay, the following chart was prepared to underscore the attributes of Kachemak Bay in toto. (Figure 35)

First to consider is the fact that the environmental values of the area were recognized through the creation of the Kachemak Bay State Park (which includes Chugashik Island along the SE border of the Fox River tidal flats) in 1970.

The biological values of Kachemak Bay were recognized by the creation of the Fox River Flat Critical Habitat in 1972 to protect extensive waterfowl populations. The Bluff Point Crab Sanctuary was, as previously mentioned, established in 1970 by the Board of Fish and Game to protect critical reproduction area.

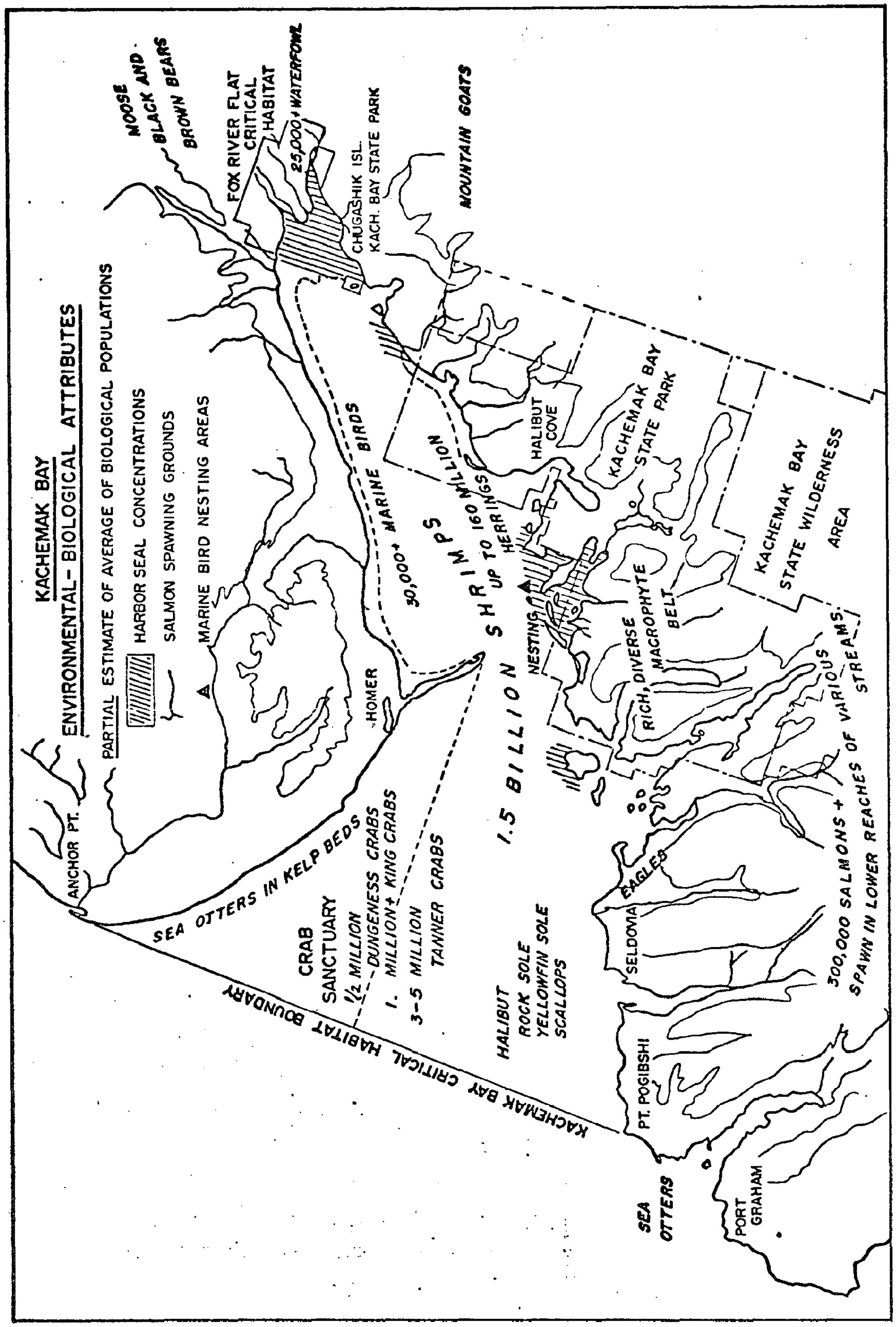
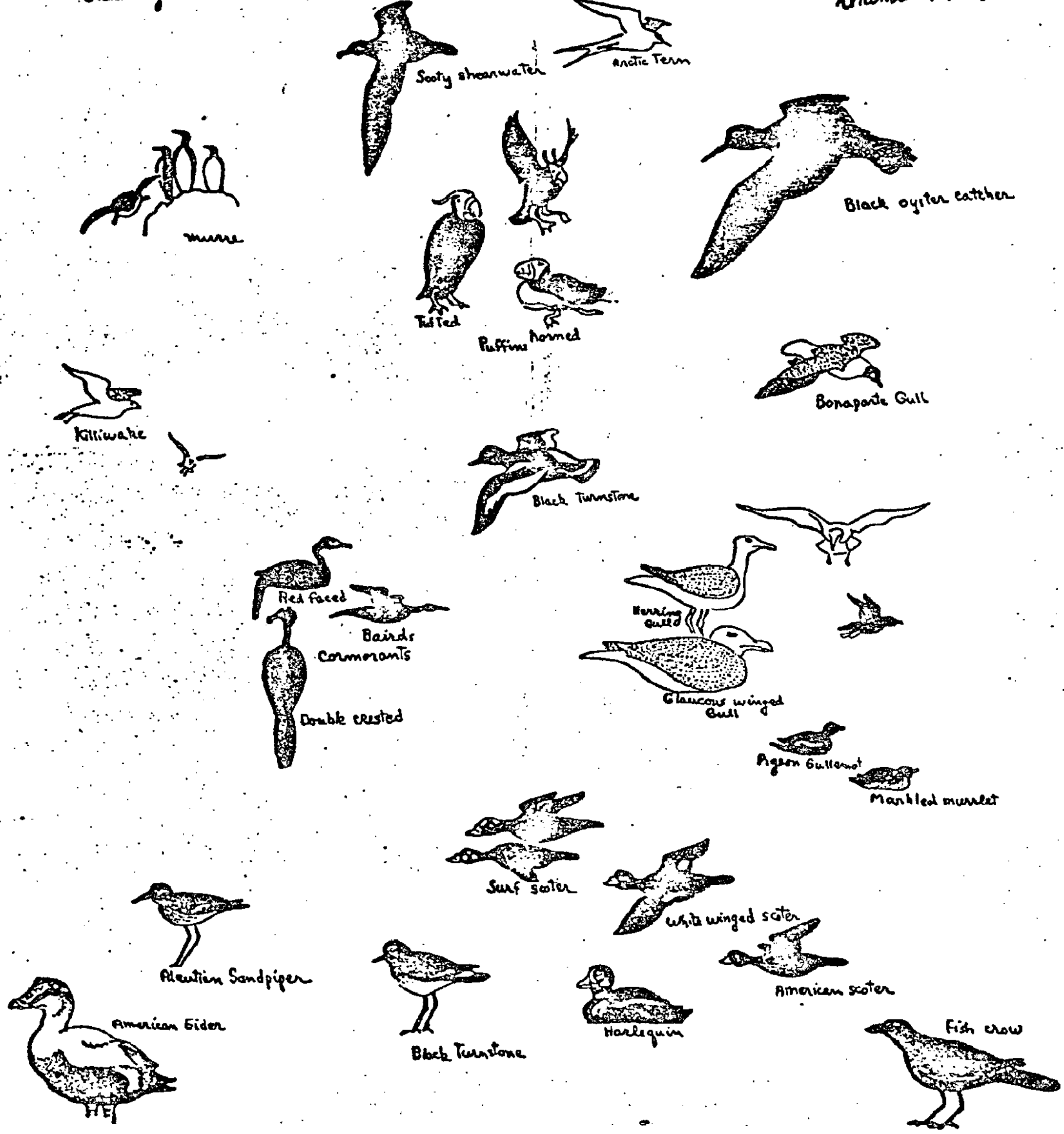


Fig. 35 Kachemak Bay - Environmental-Biological Attributes

The Most Commonly Seen Birds On Kachemak Bay

by Diana Tillion



Nesting marine birds, Gull Island

In 1974, the entire Kachamak Bay area, eastwards from a line drawn between Anchor Point and Point Pogibshi was legislatively set aside as a crucial critical habitat area.

While the progressive setting aside of State parks and critical habitat underscores the public awareness of the environmental/biological values of the area, it still does not focus on the acutal extent of the biological richness and intensity of biological utilization of the area. The estimate of the average numbers of individuals comprising what can be considered as the standing crop prior to harvest, is shown on the map of Fig. 35.

The combined sheer number of individuals, shrimps, craps, herrings, salmon, marine birds, puts a greater emphasis upon the biological attributes of the system. It must be underscored at this time that such figures are only a partial estimate of the amount of marine life utilizing or living in the bay.

The large numbers of shrimps suggest that certain areas of the bottom must be blanketed by individuals. Several studies can serve to illustrate the extent of bottom occupancy by various types of invertebrates. In March 1969, Westingouse Ocean Research Laboratory, San Diego, California while performing other duties in the Cook Inlet area, undertook for the benefit of ADF&G and other interested parties, to conduct a brief T.V. survey of selected bottom areas in Kachemak Bay. Some results of the T.V. observations are illustrated in Fig. 36. The studies conducted by NMFS indicating the total shrimp poundage per 1 mile drag can also serves to illustrate the abundance of crustacean life upon the sea floor (Fig. 37). One should note here that shrimps feed actively, and in view of their large numbers competition for food must be fierce; but to date no information is available on the spectrum of thier diet.

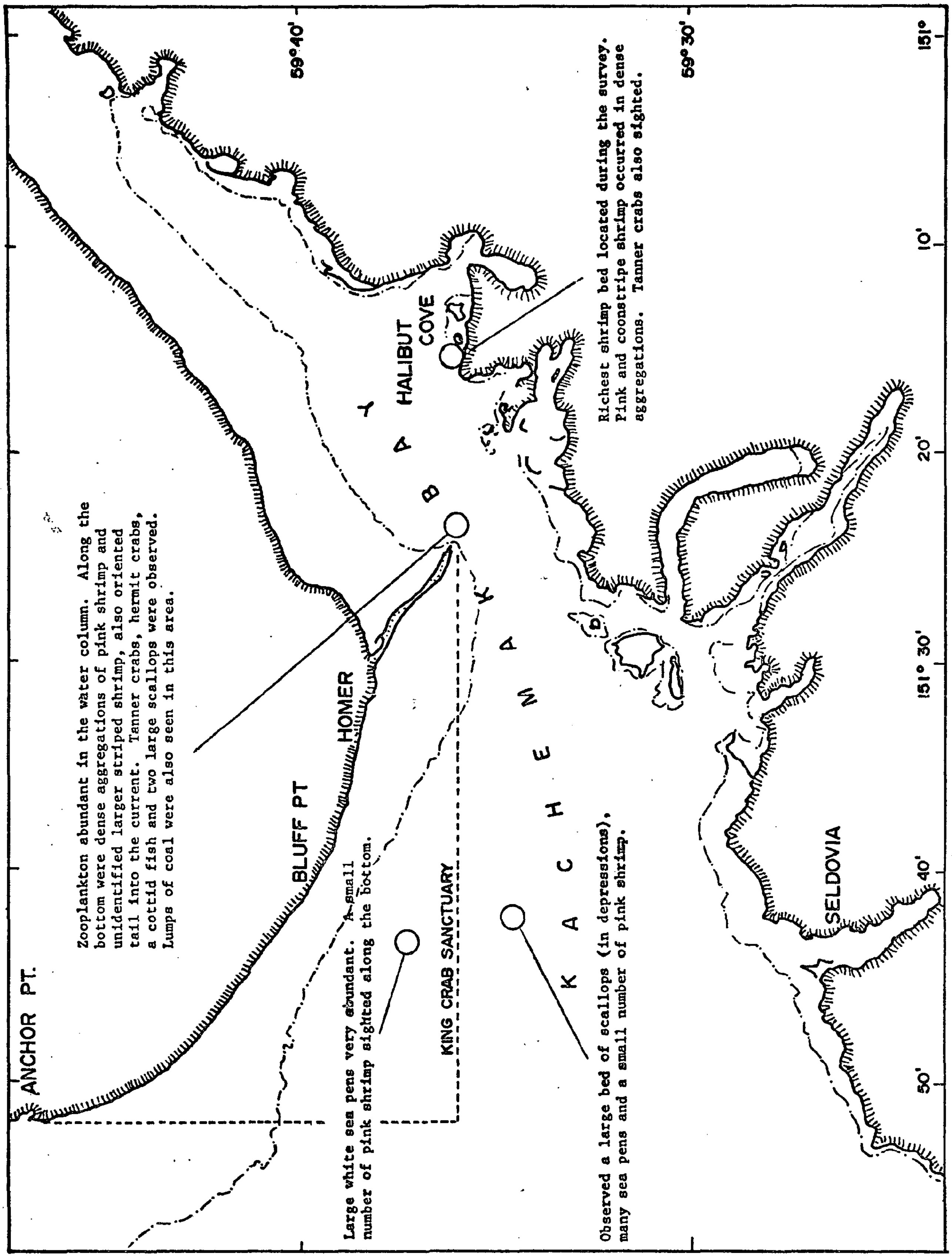


Fig. 36 - Selected Bottom T.V. Observations - (Westinghouse Ocean Research Lab - March 1969)

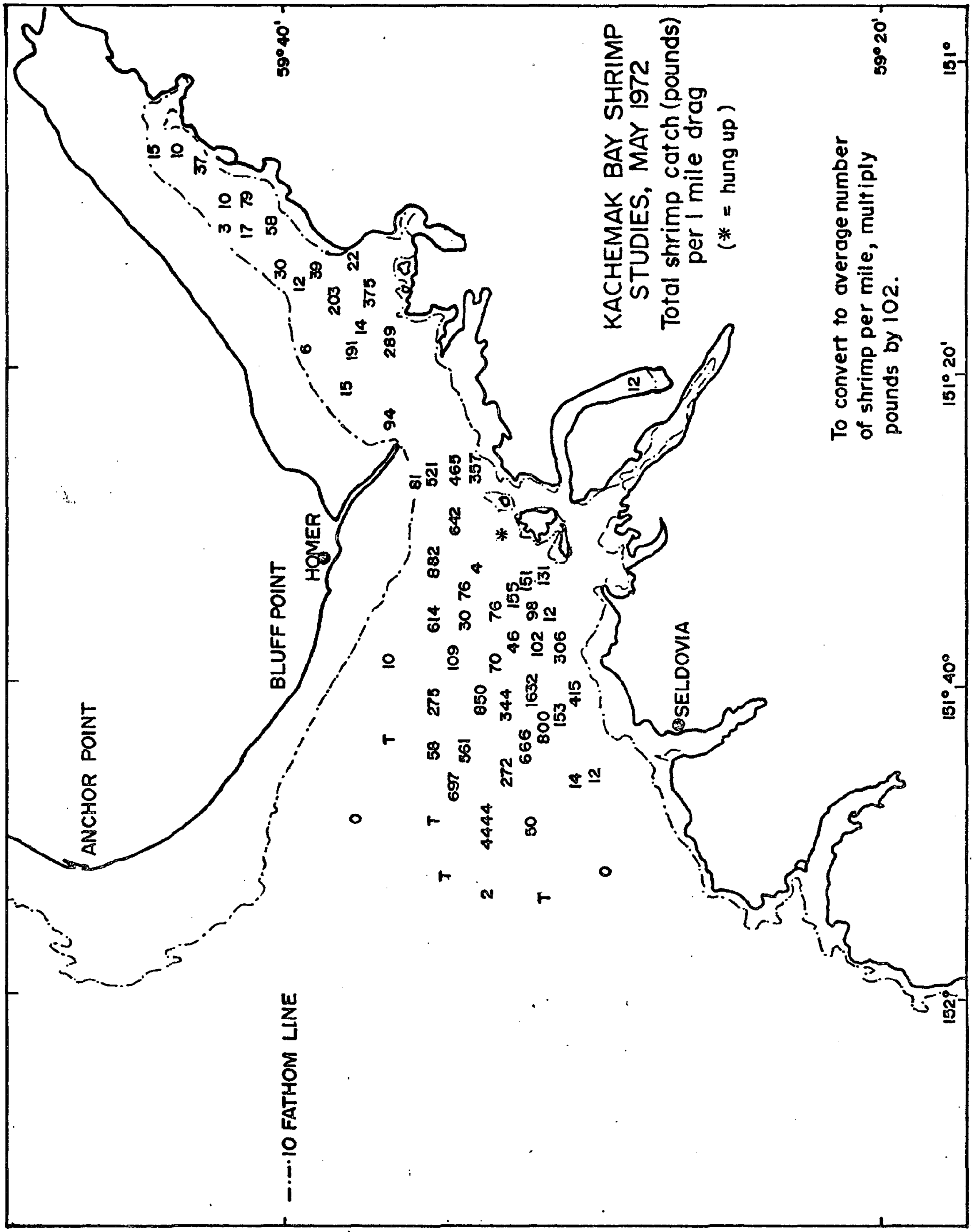


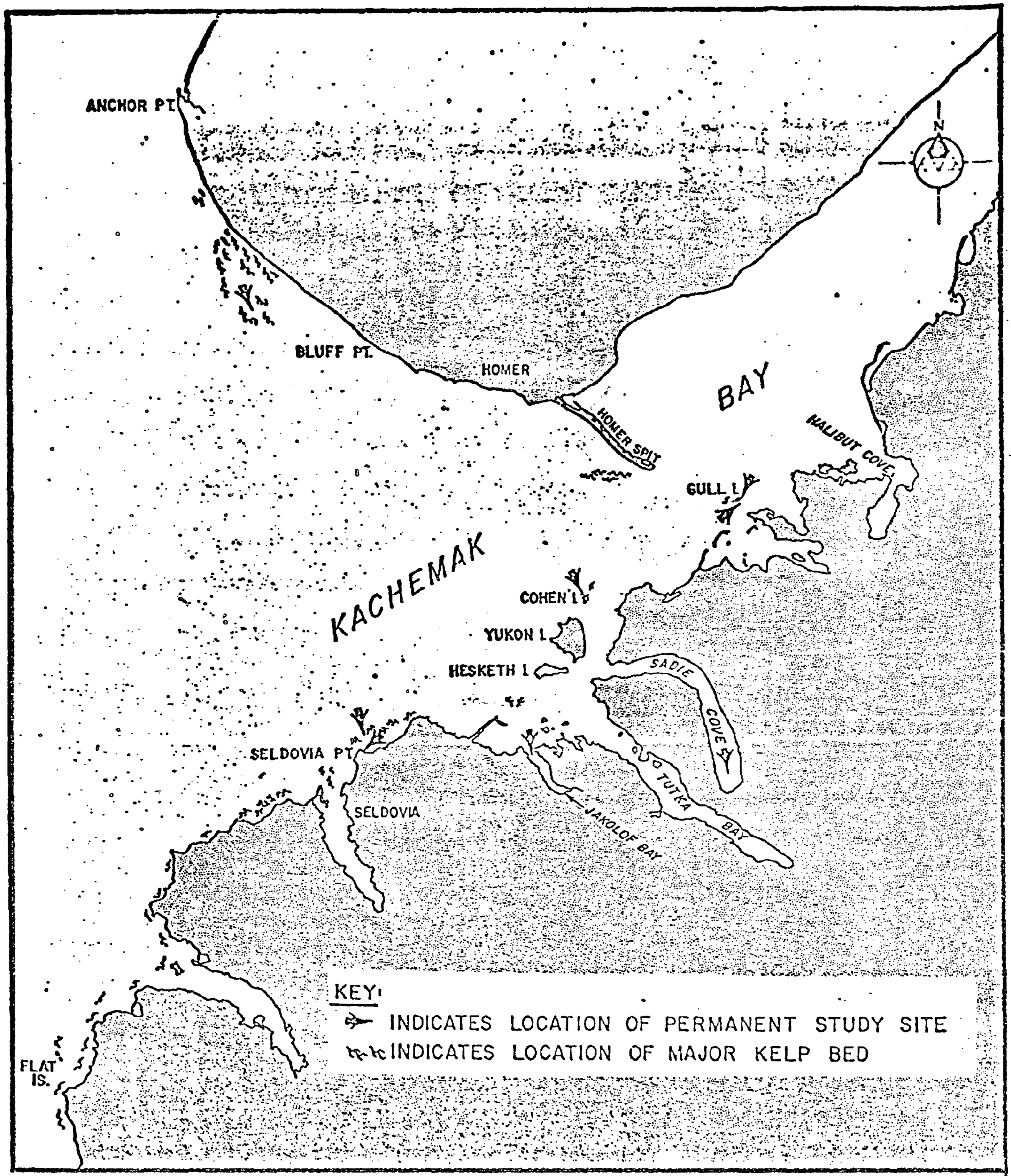
Fig. 37 - Shrimp Catches (lbs) From Trawl Investigation
Kachemak Bay. (National Marine Fisheries - 1972)

Macrophyte Ecology -- Summer 1974 - Spring 1975

One of the most conspicuous features of Kachemak Bay is the macrophyte belt. It is especially well pronounced along the southern shoreline. The term macrophyte is generally used when referring to large, attached marine plants, such as seaweeds and seagrasses. The macrophyte zone usually extends from the highest reach of the tide down to about 30m below the sea surface. The plants and animals that live within this zone are separated into two distinct environments, namely the intertidal and the subtidal. However, because of the interaction of physical and biological processes within these zones, a separation of the two habitats often becomes somewhat subjective.

Marine plant communities are highly diverse, and are known to be among some of the more productive systems on earth (Dawson, 1966; Mann, 1973). Besides the plants, these assemblages provide shelter, food and living substrate for countless numbers of nearshore organisms. In Alaskan waters, the macrophyte zone is often utilized by species of present day commercial importance such as crab, shrimp and herring.

Stands of attached marine plants are found throughout the inshore waters of southern Alaska. Some occur near areas of human population. Despite this wide distribution and nearshore occurrence these algal associations are among the most poorly understood. Because of an apparent sensitivity to changes in water quality and environmental stress, these habitats could be abused or severely impacted by man. The macrophyte zone is probably a cornerstone in the Kachemak Bay ecosystem, and any perturbation or disturbance to the plant community could affect the overall health and vitality of the Bay.



Kachemak Agal Belt Studies

Study Sites and Observations

GULL ISLAND (Semi-protected Intertidal)

Located less than 2 miles off the Homer Spit. The island is composed of sedimentary rock that rises to an elevation of 93 feet above sea level. Seaweeds formed a border around the lower margin of the island; at higher elevations terrestrial plants such as grasses and wild celery were found.

Transect lines and quadrats were placed in the intertidal zone at opposite ends (west-east) of the island. The stakes were replaced in May 1975 by more permanent stainless steel bolts and hydraulic cement. A pneumatic drill and masonry bit were used in drilling the holes for each bolt. The distance between each marker and their respective elevations were determined by metric tape and surveyor's transit and rod. On the western end of Gull Island the intertidal transect extends from the fucoid or rockweed belt to the edge of the Laminaria belt. The shoreline is irregular and the width of each algal belt appears to be highly dependent upon tidal elevation and exposure

Along the eastern end of the island the transect lines were 10m and 18m in overall length; differences in elevation were 4.25m and 5.47m, respectively. Scuba dives have been made in the sublittoral waters that encircle Gull Island.

A list of the plants and animals that inhabit the intertidal zone was started; representative algal species were collected and identified Fixed quadrats ($0.25m^2$) were photographed with 35mm film, and a drawing was made of the biota living within the borders of each quadrat. Particular attention was given to the plant and animal assemblages that adhere to rock surfaces. Percent coverage was estimated. Haphazard (random) casts were made with $0.25m^2$ quadrats at different tidal elevations. This information will be used in determining the density and distribution of the conspicuous intertidal organisms.

During spring and summer the island becomes an important rookery for sea birds such as puffin, gull, kittiwake, murre, and cormorant. Besides their physical presence, the birds appeared to play a key ecological role in the intertidal macrophyte system. In some nearshore systems, marine birds interact in a casual or limited way. However, at Gull Island, there was strong evidence to support the conjecture that sea birds, particularly glaucous gulls, entered the intertidal food chain. Gulls preyed heavily upon the green sea urchin, Strongylocentrotus drobachiensis, during low tide cycles. Predation seemed to affect not only the density and size structure of the intertidal sea urchin population but also the vertical distribution of some species of macroalgae. Sea urchins are herbivorous, and are known to exploit algal resources in other parts of Kachemak Bay. Therefore predation on herbivores such as the sea urchin possibly reduced grazing pressure on the marine vegetation.

The most notable change in the intertidal zone from season to season (1974-75) was the change in algal abundance. For example, during summer, major "dominant" species of algae such as Fucus distichus and Alaria (praelonga) covered as much as 90 percent of the rock surface. However, by fall most of the Alaria was abraided and reduced in areal cover. During the winter survey (February-March 1975), adult Alaria were rare in this location, and only immature sporophytes (2-6 cm in height) were found in the intertidal zone. By late spring these same plants had grown to cover an estimated 80-95 percent of the available substratum in the low intertidal.

Conspicuous invertebrates, such as Thais lamellosa (snail) and the sea star Evasterias trochelii, displayed seasonal variation in distribution. During summer, Evasterias density was estimated at 1.34 ind./m^2 on the southwest end of the island. However, the same area in winter had a mean density of 0.075 ind./m^2. Both Evasterias and Thais had shifted their center of distribution into the shallow subtidal zone during fall and winter.

SELDOVIA POINT (Exposed Intertidal)

Seldovia Point is a prominent land projection on the southern side of Kachemak Bay. The intertidal zone is composed of cobbles, boulders, and some bench or pavement substrata. A cliff, approximately 200 feet in elevation, rises vertically from the narrow shoreline. Seldovia Point is strategically located in terms of exposure to the waters of lower Cook Inlet.

A 50m transect line was staked into the intertidal zone running vertically from the high intertidal down to about 3m below MLLW. Elevations and zonation patterns were recorded along the transect. Fixed quadrats (0.25m^2) were photographed and mapped, percent algal coverage estimated, and numerical counts were made of the "characteristic" epifaunal invertebrates. Characteristic epifauna "were those species that were seen, and that dominated the habitat, both numerically and in terms of their demand and impact on it," (Fager, 1968).

Macrophyte sampling transect

At the seaward end of the transect, dense patches of green sea urchins were found. Samples of the intertidal sea urchin population were taken from these tidal elevations, and size frequency distributions were plotted   Macrophytes were rare in the low intertidal, and biological factors such as grazing appeared to be one reason for the absence of fleshy algae. Sea birds were uncommon in this location, so the area makes an excellent control site for the predator hypothesis we proposed for Gull Island. The larger size classes (>39mm) of sea urchins that were found to be a major part of the intertidal population at Seldovia Point were a minor constituent of the Gull Island population.

The undersides of the rocks and boulders had a reoccurring assemblage of macro-invertebrates. The association was composed of isopods, gammarid amphipods, snails, sea cucumbers, sea urchins and sea stars. Snailfish and cottids were major members of the ichthyofauna. An important predator in this association is the "6-rayed star," Leptasterias. We have begun to quantify its diet in this location, and of the 255 sea stars examined for food items, 24 were feeding on littorines, 23 balanoid barnacles and 8 mussels. As many as 25 sea stars/0.25m^2 have been observed under one rock in this location.

There was a noticeable change in the distribution and abundance of the intertidal snail, Littorina sitkana, from August 1974 to May 1975. During the summer, Littorina was found in dense concentrations in the high intertidal zone. These aggregations were highly visible, and some contained as many as 2,000 ind./0.25m^2. However, by fall most had moved to more cryptic locations such as the cracks and crevices in the pavement or boulder field. The dense aggregations of snails had not appeared by May 1975. Possibly the distribution and density change was in response to changes in the physical environment associated with storms, freezing or low ambient light level.

JAKOLOF BAY (Semi-protected Subtidal)

At the constricted entrance to Jakolof Bay, we established a fixed 25m transect line in a bed of ribbon kelp, Alaria fistulosa. The transect was placed along a shallow reef that consisted of pavement, boulders and coarse sand. Most of the study area was between 5m and 10m below the sea surface. A great deal of water movement, in the form of tidal currents, is typical of this location. For example, on a flooding or ebbing tide, the floating kelp canopy was usually pulled completely beneath the sea surface. The currents generated during extreme tides were estimated at between 2 and 3 knots, and the angle of plant deflection approached 30° with respect to the sea floor.

Adult kelp plants were tagged and their positions plotted along the 1m x 25m transect line. Adults are those individuals with reproductive blades or sporophylls. During July 1974, there were 60 adult Alaria present along the transect for a mean density of $2.4/m^2$ By October that number had been reduced to 41 plants. Concurrently, the floating canopy was reduced from an estimated 50-75 percent cover at slack tide, to 20 percent in October 1974. Adult plants were still attached along the transect; however, most had lost portions of their vegetative and/or reproductive blades. Therefore, many of the kelps no longer reached the sea surface and contributed to the floating canopy. By early

March 1975, the number of adult Alaria on the transect was 24 and the density was 0.96 ind./m^2. When we returned to the study site in May 1975, there were only three surviving adult Alaria. However, Alaria fistulosa had recruited the entire area with heavy germination along the transect line. Many of the young plants had either reached, or were approaching, the sea surface within the two-month time interval. The surface canopy now covered an estimated 50-60 percent of the underlying transect line. The ribbon kelp density along the transect was now 18.7 ind./m^2. The algal understory was also dense and was composed mainly of Laminaria, Agarum, Desmarestia and foliose reds.

Two additional underwater study plots were added in the spring; a total of 22 Alaria were measured and their positions recorded within each of the plots. This information could be useful in determining growth, mortality and recruitment.

An inventory of the biota that inhabit the reef and associated kelp bed was started. Many of the reef dwelling organisms have been photographed for future reference. Information on species abundance, patterns of distribution, and size frequency was also recorded. The food habits of a number of invertebrate species are an integral part of the information being gathered in this location. Major predators on the reef are the sea stars. A total of 432 sea stars, representing 7 species, have been examined underwater for food items. The major constituents in their diet were mussels, clams, sea urchins, sea cucumbers and anemones.

During summer months, smelt or eulachon have been observed to school in the kelp bed and feed during slack tide. Other fishes, such as greenling and sculpin, inhabit the underlying reef; however, very little is known about their movements or food habits.

To date the activities of the logging mill located near the head of Jakolof Bay have been poorly understood. Steel bands and bark from the rafted logs have been seen along the sea floor. For example, during a 20-minute swim we counted 15 steel bands scattered along the bottom at depths of 6m to 12m below the sea surface. Apparently the strong tidal currents help to keep this part of the bottom relatively free of debris, since even more bark and steel bands were found seaward of the reef.

In early March 1975, we found juvenile king crabs hiding under bark and within the rock-vegetation understory approximately 100m northwest of the kelp bed. Species of pandalid and hippolytid shrimp were also important constituents of the understory habitat.

In summary, the underlying reef supported an interesting array of benthic organisms. Most of the inhabitants are morphologically adapted to take full advantage of the extremes in water movement. Possibly this location is one of the more productive shallow water areas in Kachemak Bay.

SADIE COVE (Semi-protected Subtidal)

At the head of Sadie Cove, we established a fixed subtidal station just above the 16-fathom contour. Two transects, each 25m in length, were placed on the bottom at depths of 5m and 8m below the sea surface. An additional station was added in October 1974 at a depth of 30m within the basin.

The study area consisted of sand, silt and mud. Clam shells provided most of the available solid substratum. Low statured kelps such as Laminaria saccharina either drifted along the bottom, or remained loosely attached to shells and small stones. During the summer these kelps were bleached and flaccid in appearance; however, by fall most were robust and fertile.

In the summer 1974, the cove was an important habitat of tanner crab, dungeness crab, horse crab and decorator crabs. Pandalid shrimp were abundant both along the slope and within the 16-fathom basin. Most of the shrimp used either clam shells or kelp debris for cover. Cancer magister was seen in the shallow (4m-15m) portions of Sadie Cove, either partially buried in the sediment or hiding under the macrophytic understory. Most were adult males; however, a few females were collected and released during the fall survey. The horse crab, Telmessus cheiragonus, was the most abundant crab seen in the Cove during July-August. Usually this species was closely associated with the near bottom kelps. For instance, of the 80 Telmessus observed either along the transect lines or within the study area, 67 or 84 percent were using the kelps for either forage or cover. During July and August 1974, we counted 19 mating pairs of Telmessus; density was estimated at 0.24 ind./m^2. In October there were only a few pairs of horse crab observed in the area, and by winter there were no horse crabs seen along the transect lines. Telmessus was returning to the study site during the spring 1975 survey.

Dungeness crab exhibited a similar change in distribution and abundance. This is a ubiquitous animal in this location during the summer and fall; however, by late February 1975, only two individuals were seen throughout the entire study site. Adult dungeness crab had returned to the shallow water flats in Sadie Cove by May 1975.

Another readily apparent seasonal change was the appearance of the king crab during the winter study period. While diving along the 16-fathom contour on February 26, 1975, we encountered two pods of king crab sitting along the bottom. Each aggregation was composed of between 30-50 crabs; the sex ratio was not determined. This was the first encounter with adult king crabs in Kachemak Bay, and these *in situ* observations in Sadie Cove agree with the migration findings of Bright (1967).

Another conspicuous group of animals in this shallow water assemblage are the bivalve clams. The gaper clam, *Tresus capax* was the most abundant clam seen on the shelf. Estimates of clam density were made along both of the fixed transects. *Tresus* was usually visible because of the siphon that extended above the substratum. Other common bivalves in this location were the cockle, *Clinocardium*, and the butter clam, *Saxidomus*. The sea stars, *Pycnopodia* and *Evasterias*, prey upon the various clam species in Sadie Cove. Both are capable of removing the clams from the substratum by digging. Upon completion of a feeding, the empty shells are discarded along the bottom. These shells not only provided attachment sites for the macroalgae, but also substrate and cover for invertebrates and fishes alike.

One of the major objectives in this location is to document habitat requirements and energy flow in this near bottom kelp ecosystem.

SELDOVIA POINT (Exposed Subtidal)

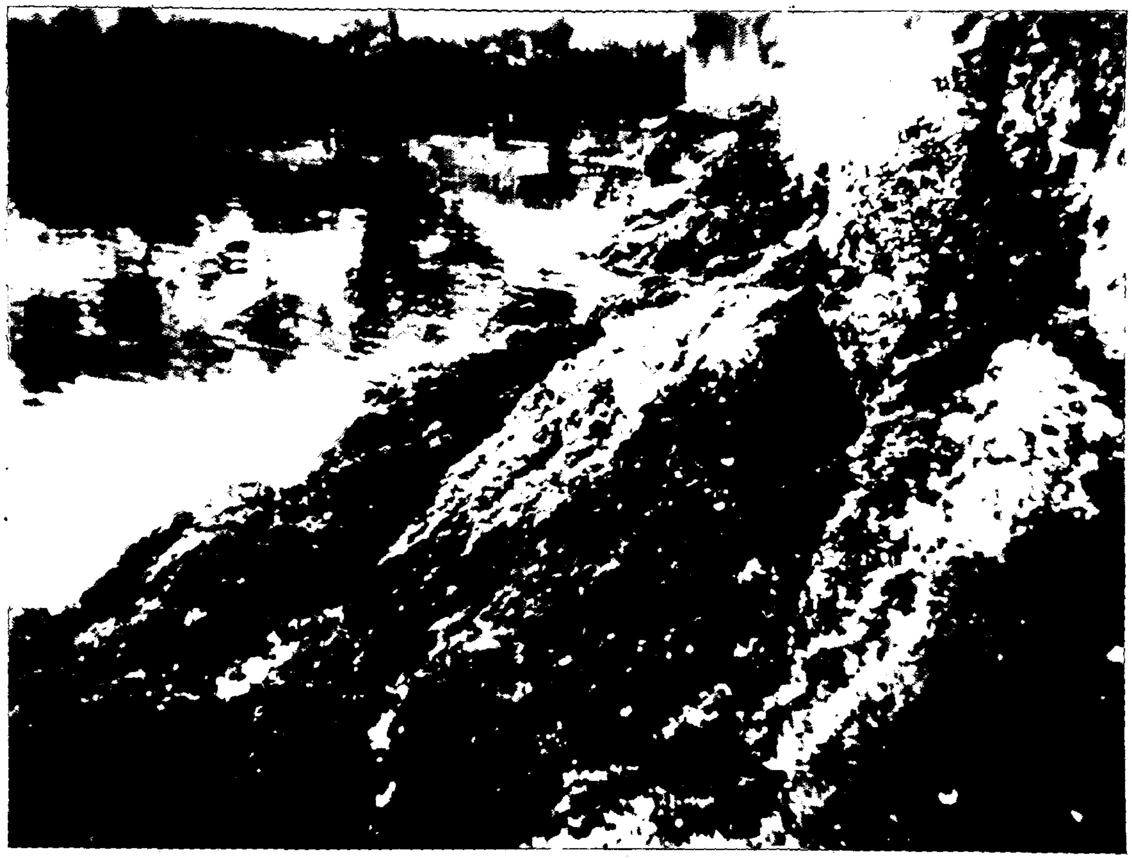
The largest and most conspicuous kelp bed in Kachemak Bay was found in the vicinity of Seldovia Point. A major part of the bed was located off the northeast side of the Point. There is historical evidence for the occurrence of the Seldovia kelp bed since the early 20th Century (Cameron, 1915).

During July and August 1974, the floating kelp canopy was composed of two species of algae, *Alaria fistulosa* and *Nereocystis luetkaena*. *Nereocystis*, or bull kelp, occurred predominantly nearshore, and *Alaria* was more abundant on the outside edge of the bed. The summer canopy covered an estimated 80-90 percent of the underlying sea floor.

A 25m transect line was placed in 10m-12m of water during July 1974. The bottom was composed of cobbles, boulders, pavement and sand. Individual kelp plants were tagged and their positions were plotted along the transect. In July there were 103 kelp plants present within this 25m strip of sea floor; however, by October all of the plants had disappeared.

Alaria was the most abundant kelp in the floating canopy during summer. By October the kelp most often seen on the sea surface was *Nereocystis*. There were attached *Alaria* plants in the study site; however, most had abraided fronds or blades that no longer reached the surface of the water.

Another transect line was added to the sampling array in October. This line was 15m in length and was located approximately 100m inshore from the other transect. The position of the kelps was mapped along the line, and the composition of the algal understory was recorded.



Fucus zone, upper intertidal level

Conspicuous plants and animals were either collected or identified. The food habits of a number of species were recorded and photographs were taken. Night dives were also made during the hours of 2100-2300. Pandalid shrimps were extremely abundant on the understory kelps and associated rocks in the evening hours. Kelp holdfasts were examined underwater, and most were found to contain small crabs and shrimps.

CRAB SANCTUARY (Exposed Subtidal)

A series of dives were made in the kelp beds that fall within the boundary of the crab sanctuary off Anchor-Bluff Point. The dives were made during July and August 1974 at depths between 8m and 25m below the surface. The sea floor consisted of flat pavement, large boulders and patches of sand. Coralline algae encrusted much of the solid substratum. A fixed transect line and marker buoy were placed at a depth of 10m to 12m below MLLW. When the thin veneer of encrusting algae was penetrated by the transect stakes, it exposed an underlying layer of coal.

The marine plant community was "dominated" by Alaria fistulosa. The estimated mean density of adult Alaria was 2.2 ind./m^2 and 5.2/m^2 for plants without sporophylls The other member of the floating canopy was Nereocystis. This species was not as abundant, and we estimated the density at 0.1/m^2.

The algal understory consisted mainly of Laminaria and Agarum. Strongylocentrotus droebachiensis was very abundant. The size structure of the urchin population was remarkably similar to the intertidal population at Seldovia Point. Density estimates ranged from 27 ind./m^2 to 31 ind./m^2, depending on the sampling method.

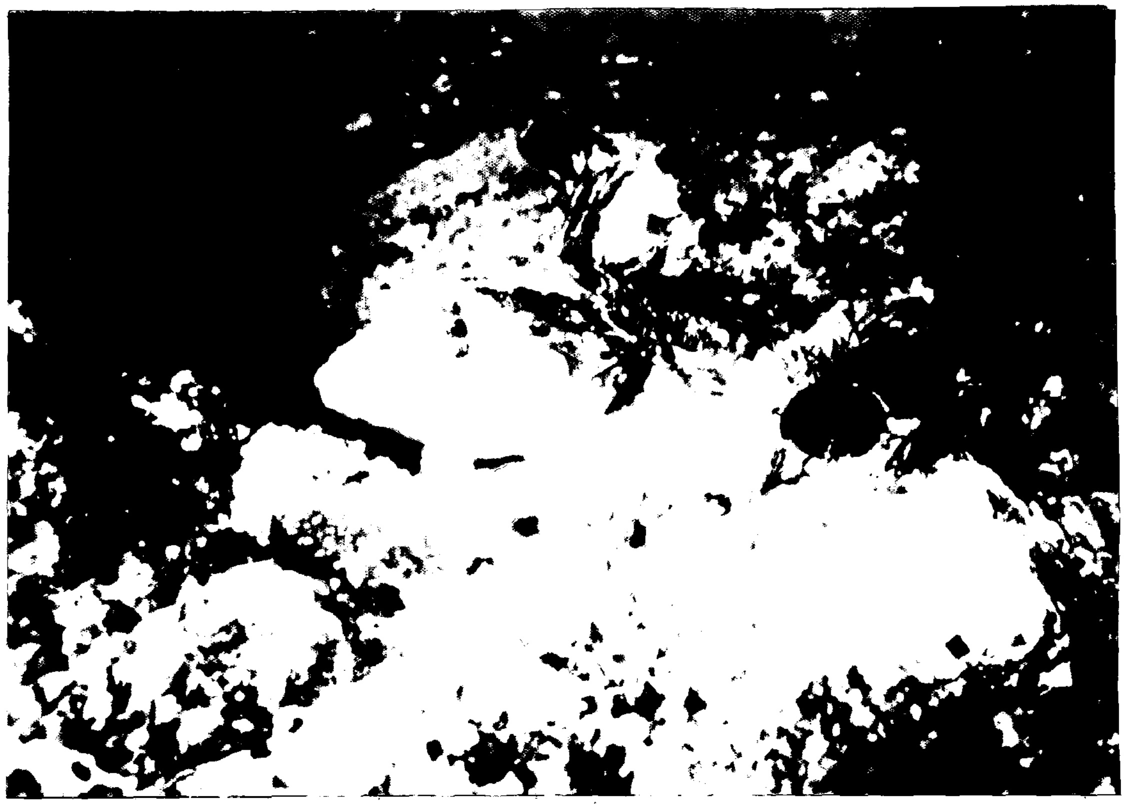
Further offshore the bottom was composed of more boulders and rock outcroppings. The Alaria bed was less pronounced at a depth of 15m. The algal understory is more luxuriant and robust. Laminaria, Agarum and foliose reds "dominate" the macrophytic understory. In some areas, particularly along the shoreward edge of the "Standard Oil Lease," the sea urchins have grazed the macrophytes down to a coralline pavement. This is an area of high water motion. Sabellid worm tubes carpeted the sea floor. Desmarestia viridis and D. ligulata were found growing on the worm tubes. The invertebrate assemblage reflected this high water motion environment. The bottom supported an extremely diverse biota; conspicuous forms such as polychaete worms, bryozoans, sea anemones, tunicates, barnacles and sponges formed the epifaunal crust.

COHEN ISLAND (Semi-protected Intertidal)

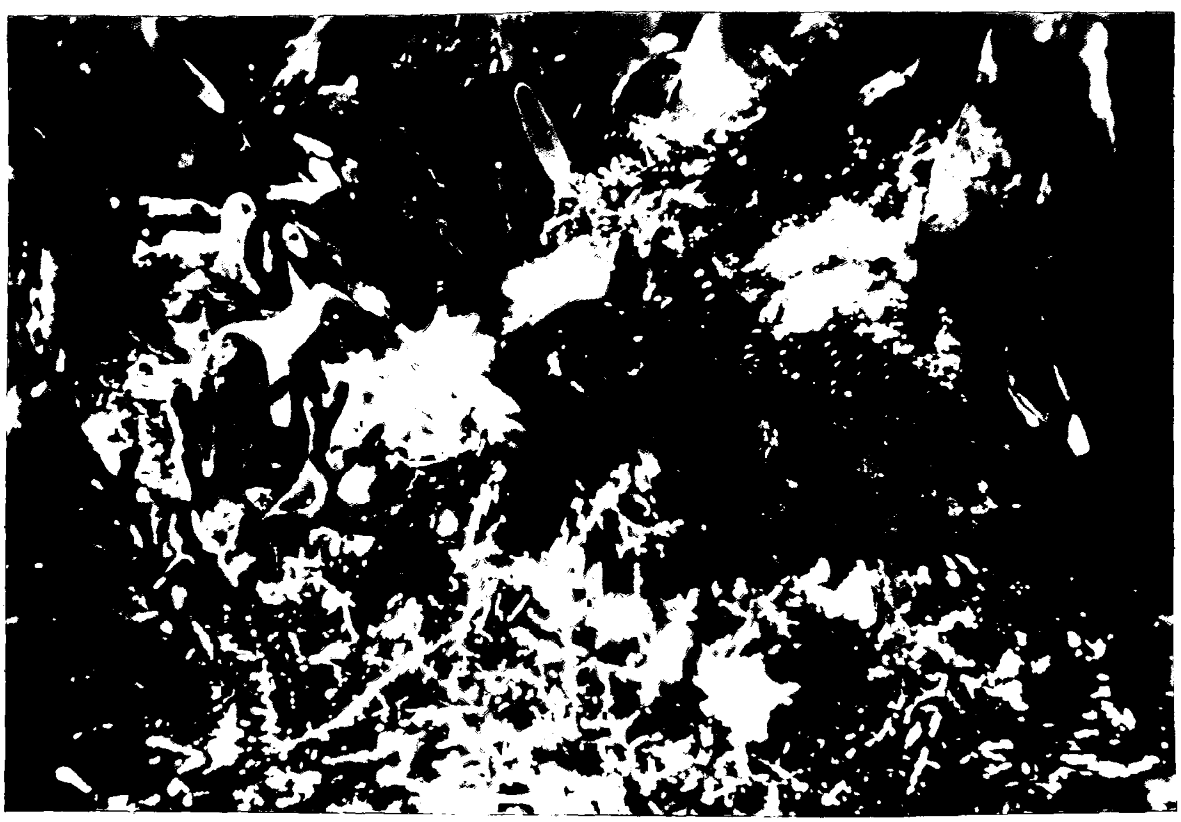
A small islet off the northwest end of Cohen Island was the location of this study site. A 25m transect line was established in the rocky intertidal zone. The line ran from the high intertidal down to MLLW. Plants and animals were collected and photographed; fixed $0.25m^2$ quadrats were mapped and photographed. Numerical information on biomass, conspicuous invertebrates present, size frequency distributions, and usage of the macrophyte belt by adult and/or juvenile crustaceans were recorded. Cohen Island and Gull Island appeared to be similar in terms of plant and animal components of the intertidal ecosystem

ARCHIMANDRITOF SHOALS

Approximately 1 mile off the Homer Spit is a shoal area known as Archimandritof. Bull kelp, Nereocystis, grows along this area, and



Guarding the nest



Camouflage

during August 1974 we estimated, from an aerial survey of Kachemak Bay, that this kelp bed was approximately 1-1.5 miles in length and between 100-200 meters wide. During low or slack tide, the floating canopy was visible on the sea surface. In the fall 1974, we made a reconnaissance dive in the kelp bed. Mature bull kelp was growing 5-6m below the sea surface on solid substratum overlain by unconsolidated fines such as silt and sand. Silt covered not only the rocks but also most of the low statured macrophytes. The algal understory was dominated by Laminaria groelandica and Agarum cribrosum. Green sea urchins grazed on both the understory and the holdfasts of the attached bull kelp. Juvenile tanner crabs and pandalid shrimps were extremely abundant in this location. Juvenile pandalids were estimated at between 8-10 ind./m^2; most of the tanner crabs were seen on soft substratum adjacent to rock. Many of the sea urchins had abraided spines and tests.

Other common invertebrates in this location were the sea star, Evasterias; rock jingle, Pododesmus cepio; sea star, Crossaster papposus; whelk, Fusitriton oregonensis; and the clam, Mya truncata.

SUMMARY

During the summer and fall 1974 and winter 1975 field surveys, 89 species of macroalgae were collected within Kachemak Bay. Many of these species represent geographical range extensions.

Commercial Fisheries of Kachemak Bay - An Overview

Kachemak Bay, located in lower Cook Inlet, is 35 miles long, averaging ten miles in width and totalling about 350 square miles (Figure 1). It is one of the most highly productive marine environments in the state of Alaska and probably one of the richest bays in the world on a per unit of area basis. Commercial fisheries harvest data and research results from marine investigations are supportive of this statement.

Salmon were first harvested commercially from the Bay near the turn of the century and were the main species taken until 1914 when a commercial herring fishery started up. The herring fishery which was centered in the Halibut Cove area was active for 15 years during which time nearly 90 million pounds of herring were produced in Kachemak Bay. At the conclusion of the herring fishery in 1928 salmon again were the mainstay of the commercial fishery until 1951 when a sustained commercial effort began on king crab. Since 1951 over 40 million pounds of king crab have been harvested from Kachemak Bay and the Bay presently has an annual quota of 2.0 million pounds.

Shrimp was the next commercial fishery to start on a sustained basis in Kachemak Bay in 1959 followed by dungeness crab in 1961 and tanner crab in 1968. There had also been some sporadic effort on dungeness in the 1950's.

Pacific halibut have also been taken commercially in Kachemak Bay for a number of years, however, records kept by the Halibut Commission do not show a breakdown between Kachemak Bay and the adjacent lower Cook Inlet area.

In addition to commercial fisheries there are substantial subsistence and sports fisheries in Kachemak Bay which harvest all of the above mentioned species plus several species of bottom fish and clams. The subsistence fishery is the highest use subsistence fishery in the Cook Inlet area and probably in the state of Alaska although accurate records are not kept statewide to determine this. The Kachemak Bay sports fishery in terms of man days of effort expended was the highest use sports fishery in the state in 1973. Over 31,000 man days of effort was recorded between June and September. (Sports Fish Investigations of Alaska, 1974 Report)

Kachemak Bay is not only uniqũe as judged by it greatly diverse and highly productive marine fisheries. It is unique in many other ways. At various seasons of the year the Bay harbors tremendous concentrations of shore birds, sea birds, and waterfowl. There are several species of marine mammals including harbor seals, porpoises, sea otters, sea lions and several species of whales which are common in the Bay. Several major big game species including black bear, brown bear, moose, mountain goats, and Dall sheep inhabit the shore line and adjacent mountainous area around Kachemak Bay. All of the above forms of life are found elsewhere in the state of Alaska. But no where else in the state can one find the diversity and abundance of life all together in one place as it is in the Kachemak Bay area. You add to this the fantastic scenic qualities of the area and this is what makes Kachemak Bay so unique.

This report will attempt to document the biological values of Kachemak Bay by summarizing the commercial catch and production figures as well as some of the various marine research projects which have taken place and are currently taking place in Kachemak Bay.

II. COMMERCIAL FISHERIES

Commercial fisheries in Kachemak Bay take place on five species of Pacific salmon (Oncorhynchus), five species of shrimp (Pandalid), three species of crab (king, tanner and dungeness), Pacific herring, and Pacific halibut. All catch records are kept by the Alaska Department of Fish and Game except for halibut which is tallied by the Pacific Halibut Commission. During the last five years (1970-75) the total production in pounds for all commercial species in Kachemak Bay has averaged just over 11 million pounds per year (Table 1). The annual value to fishermen and the first wholesale value to processors fluctuates tremendously with market conditions and prices. The peak year during the last five years was 1973 when a total harvest of more than 12.0 million pounds was worth about $3.2 million to fishermen and about $7.3 million on a first wholesale basis (Table 2). The importance of Kachemak Bay to the entire Cook Inlet area shellfisheries is exemplified in Table 3 which shows the percent of total Cook Inlet shellfish production by species, contributed by Kachemak Bay. Since 1964 nearly 60 percent of all shellfish harvested have come from Kachemak Bay.

The number of vessels participating in the various Kachemak Bay commercial fisheries during 1973 was as follows: King crab-56, tanner crab-80, dungeness crab-53, pot shrimp-40, trawl shrimp-8, herring-12, and salmon-60. Figures for halibut are not available, however, a conservative

Table 1. Kachemak Bay, Cook Inlet, Commercial

Fisheries Harvest, 1966-75

Year	Kings	Reds	Cohos	Pinks	Chums	Total
1966	60	12,192	4,535	177,544	28,754	223,085
1967	173	26,350	2,393	95,100	23,416	147,432
1968	61	18,716	4,671	154,033	4,518	181,999
1969	59	12,578	485	70,753	2,600	86,475
1970	91	12,245	3,705	208,174	8,174	232,389
1971	41	18,403	3,151	50,066	2,857	74,518
1972	69	31,345	1,283	9,126	4,936	46,759
1973	139	24,072	1,241	97,574	3,588	126,614
1974	182	27,029	3,054	48,875	2,725	81,865
1975 1/	138	27,385	1,240	866,335	5,411	900,509

Shellfish (Pounds)

Year	King Crab	Tanner Crab	Shrimp	Dungeness Crab
1966	1,910,364		309,676	12,523
1967	1,279,708		741,438	7,168
1968	996,520	146,491	26,030	484,452
1969	1,302,554	1,436,680	1,849,710	49,894
1970	1,501,288	1,152,609	5,815,268	209,819
1971	1,251,142	1,186,488	5,438,091	97,161
1972	1,900,006	2,942,082	5,450,498	38,930
1973	2,114,841	3,763,060	4,709,486	308,777
1974	1,609,530	1,106,263	5,740,647	721,183
1975 2/				

Herring

1969	1.1 Million Pounds
1970	5.4 Million Pounds
1971	25,000 Pounds
1972	2,000 Pounds
1973	407,500 Pounds
1974	219,359 Pounds
1975 1/	48,833 Pounds

1/ 1975 data preliminary.

2/ Shellfish seasons still in progress.

TABLE 2. ESTIMATED VALUE IN MILLIONS OF DOLLARS OF KACHEMAK BAY COMMERCIAL FISHERIES IN 1973

SPECIES	VALUE TO FISHERMEN	FIRST WHOLESALE VALUE
SALMON	.2	.4
KING CRAB	1.7	3.3
TANNER CRAB	.7	1.7
SHRIMP	.4	1.5
DUNGENESS CRAB	.2	.4
HERRING	.03	.06
TOTAL	3.2	7.3

le 3. Percent of Total Cook Inlet Shellfish Production (pounds) Contributed by Kachemak Bay, 1964-1974.

Year	Dungeness Crab	King Crab	Tanner Crab	Shrimp	Total
1964	94.9	26.0		98.1	35.3
1965	100.0	65.3		100.0	67.0
1966	10.5	48.4		100.0	51.0
1967	100.0	41.2		100.0	52.6
1968	99.3	25.1	97.4	98.1	35.7
1969	100.0	45.6	98.7	100.0	74.7
1970	100.0	38.5	86.9	99.9	77.2
1971	100.0	29.8	55.9	99.8	67.3
1972	99.4	41.3	61.2	98.3	68.9
1973	98.5	47.7	46.4	97.4	61.9
1974	99.9	34.8	14.4	99.8	49.2
AVERAGE	94.4%	38.6%	45.8%	99.1%	59.8%

estimate would be that about ten halibut vessels fished in Kachemak Bay during 1973. From one to four crewmen assist the skipper on each vessel depending on the size of the vessel and the fishery engaged in, although, most fishing boats in Kachemak Bay utilize a crew of two in addition to the skipper. Using the above figures one can get a general idea of the number of fishermen who utilize Kachemak Bay, however, it is difficult to come up with an exact figure since some fishermen engage in several different fisheries. There are four major and several minor fish processors who depend on product from Kachemak Bay for their operations. Major processors are Alaska Seafoods (Homer), Whitney Fidalgo (Homer and Port Graham), Wakefield Seafoods (Seldovia), and Seward Fisheries (receiving station in Homer). A general discussion on each of the major commercial fisheries follows.

Salmon The major portion of salmon taken in Kachemak Bay are taken with seine gear and the major species caught are pink salmon. Pink salmon have made up 82.7 percent of the catch since 1954 followed by Chum salmon (8.2 percent), sockeye salmon (7.8 percent), coho salmon (1.2 percent) and king salmon (.1 percent). The average total salmon catch for Kachemak Bay since 1954 is 248,886 (Table 4).

Kachemak Bay is separated into four major catch zones with each zone containing one of the four major pink salmon streams (Figure 38 2). Zone A, upper Kachemak Bay, contains Humpy Creek and the yearly catch in this area has averaged 67 thousand pink salmon since 1961. Zone B contains Tutka Creek and has produced an average pink catch of 64 thousand since 1961. Seldovia River is the main producer in Zone C and this area has averaged 53 thousand pink salmon since 1961. Area D contains Port Graham stream and this area has averaged 8 thousand pink salmon since 1961.

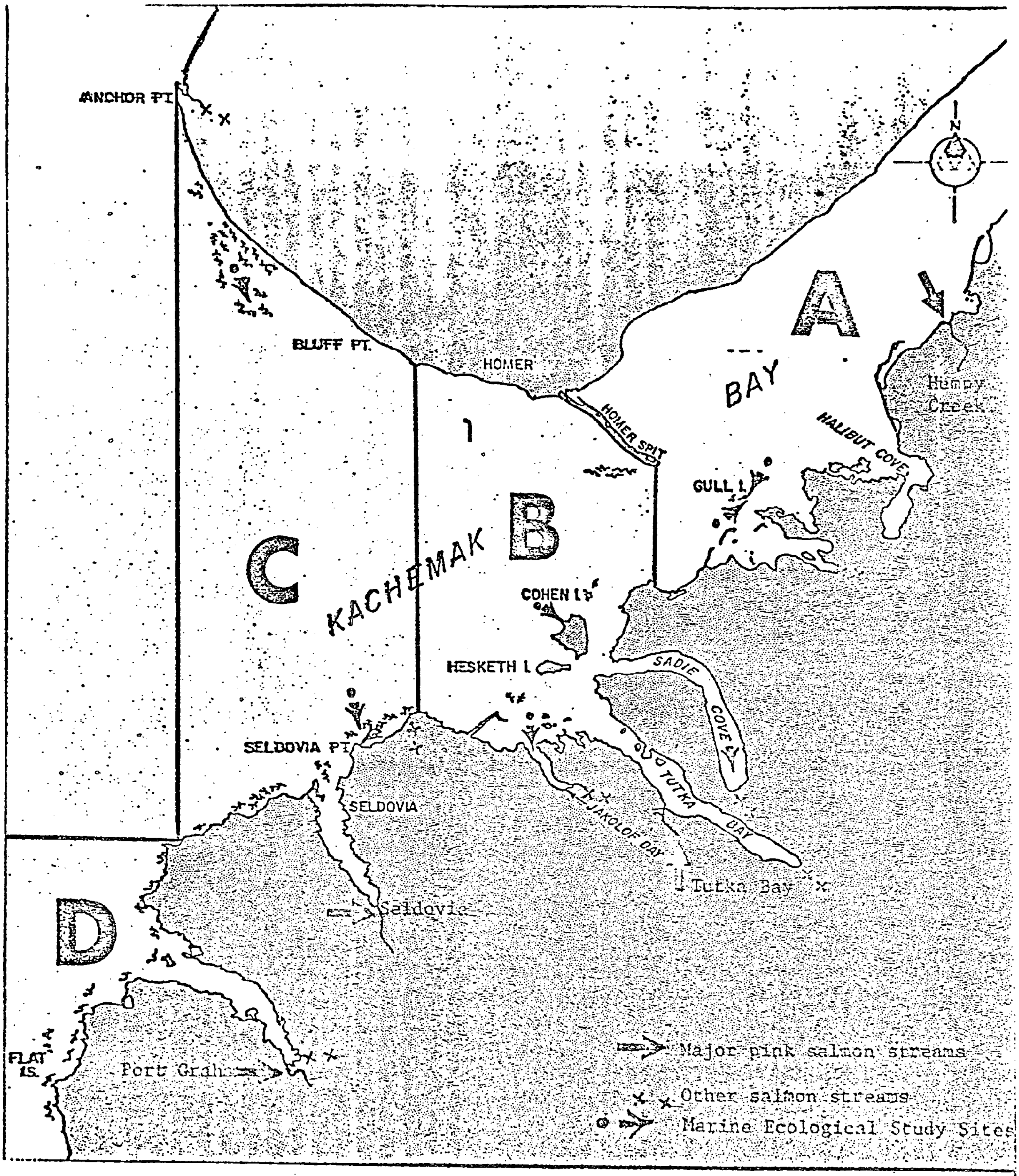


Figure 38. Kachemak Bay salmon streams and commercial salmon catch zones.
A Upper Kachemak B Tutka C Seldovia D Port Graham

Table 4.

Kachemak Bay District

Salmon catch, by species, 1954-1975

Year	Kings	Sockeyes	Cohos	Pinks	Chums	Total
1954	1,522	22,913	12,235	180,977	150,769	368,426
1955	562	30,848	3,230	565,216	24,398	624,254
1956	310	33,054	4,693	150,486	53,515	242,058
1957	286	19,431	1,507	130,511	57,403	209,138
1958	119	17,731	1,713	209,798	24,096	253,457
1959	74	10,026	709	50,076	15,278	76,163
1960	12	12,292	1,237	250,818	4,100	268,459
1961	39	10,180	1,161	191,911	2,924	206,215
1962	58	16,569	2,095	564,050	9,089	591,861
1963	88	13,142	4,020	99,829	7,695	124,774
1964	84	17,283	8,905	266,489	11,529	304,290
1965	10	11,229	733	90,330	2,459	104,761
1966	60	12,192	4,535	177,544	28,754	223,085
1967	173	26,350	2,393	95,100	23,416	147,432
1968	61	18,716	4,671	154,033	4,518	181,999
1969	59	12,578	485	70,753	2,600	86,475
1970	91	12,245	3,705	208,174	8,174	232,389
1971	41	18,403	3,151	50,066	2,857	74,518
1972	69	31,345	1,283	9,126	4,936	46,759
1973	139	24,072	1,241	97,574	3,588	126,614
1974	182	27,029	3,054	48,875	2,725	81,865
1975 1/	138	27,385	1,240	866,335	5,411	900,509
TOTAL	4,177	425,013	67,996	4,528,071	450,234	5,475,491
AVERAGE	190	19,319	3,091	205,821	20,465	248,886
PERCENT	.1	7.8	1.2	82.7	8.2	100.0

1/ Preliminary Alaska Department of Fish and Game fish ticket count.

Port Graham is capable of producing many more fish, however, stream stabilization and rehabilitation are needed. The catches for the four zones described above, by year since 1961, appear in Table 5.

Preliminary catch figures for Kachemak Bay for 1975 indicate it will be the highest year on record with a total salmon catch of over 900 thousand. The bulk of this year's catch were pink salmon (866,335). The peak escapement counts in 1975 for the pink salmon run to Kachemak Bay totaled 120 thousand to the four major streams (Table 6). Final escapement has not yet been tabulated, however, as a general rule the peak counts tallied in the streams at the height of the pink run usually account for about 60 percent of the total season's escapement. If this rule holds true for 1975 the total pink salmon escapement in the Kachemak Bay area will reach about 200 thousand thus making a total run to the bay of over one million pink salmon.

The record pink run is attributed to a conservative management approach in the past and excellent stream and ocean survival conditions. The maintenance of a pollution free and undisturbed habitat will be a critical factor in determining whether Kachemak Bay can produce runs of this magnitude in future years. Since much of the spawning takes place in the intertidal areas of the streams and since juvenile salmon spend the first few months after stream emergence in nearby areas, it is especially important to the survival of salmon that the waters of the bay maintain their high quality.

Table 5. Kachemak Bay district pink salmon catch by area. 1/

Year	A Upper Kachemak	B Tutka	C Seldovia	D Port Graham
1961	68	107	16	1
1962	110	291	145	10
1963	58	38	2	2
1964	83	101	44	36
1965	14	6	19	10
1966	42	54	59	7
1967	40	36	12	4
1968	46	29	56	19
1969	1	37	31	2
1970	114	45	29	11
1971	11	10	27	1
1972	3	5	.2	.9
1973	44	20	19	13
1974	35	5	3	3
1975 2/	342	173	334	6
TOTAL	1,011	957	796	126
AVERAGE	67	64	53	8

1/ See Figure 2 for catch zones.

2/ Preliminary Alaska Department of Fish and Game fish ticket count.

Table 6. Kachemak Bay area, estimated pink salmon escapements in thousands of fish.

Stream	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975 1/
Humpy	56.0	34.7	18.5	28.0	30.0	25.0	24.7	5.4	55.2	45.0	13.8	36.9	17.4	39.7
Tutka	30.0	10.0	20.0	20.0	12.0	7.0	7.9	6.5	6.5	16.7	1.5	6.5	2.6	20.1
Seldovia	50.0	15.0	60.0	30.0	86.0	55.0	53.2	60.0	23.0	31.1	5.8	14.5	13.7	37.6
Pt. Graham	50.0	2.0	16.0	1.5	24.0	2.0	24.4	4.0	16.6	13.2	2.4	7.0	2.8	22.6
TOTAL	186.0	61.7	114.5	79.5	152.0	89.0	110.2	75.9	101.3	106.0	23.5	64.9	36.5	120.0

1/ Peak stream count for 1975. Total escapement has not yet been determined, however, is estimated at 200 thousand.

King Crab

The king crab fishery in Cook Inlet started on a commercial basis in 1951. Both trawls and pots were used and effort was concentrated in Kachemak Bay. A total of 6,619 pounds of king crab was landed. In 1952 there was very little effort and the catch was only 2,900 pounds, occurring in the late summer. 1953 was the first year of any considerable production of king crab in Kachemak Bay, as effort was accelerated and 1.3 million pounds were taken. Pots, trawls, and tangle-nets were used and effort was concentrated in August and September. About 12 boats participated in the fishery.

The fishery developed slowly between 1953 and 1959 and the average production during this period was 1.4 million pounds, nearly all caught in Kachemak Bay.

A jump in production occurred in 1960 when 60 boats registered for king crab. Although only 35 of these boats participated inthe fishery at any one time, the catch jumped up to 4.3 million pounds. Prior to 1961 nearly all of the king crab catch in Cook Inlet came from Kachemak Bay. In 1961 the bay was still the main producer with 3.0 million pounds, however, 1.3 million pounds were also taken in Kamishak and the Outer districts. Throughout the 1960's Kachemak Bay averaged about 2.0 million pounds of king crab annually and in 1969 the Alaska Board of Fish and Game established a 2.0 annual million pound quota which is still in effect. The fishing season was also reduced tremendously with the season established from August 1 to February 28 to protect king crab during their breeding, molting, and soft shell period. The season was changed again in 1973 when the closing date was extended two weeks to March 15. In 1973 a total of 56 different vessels landed 2.1 million pounds of king crab from Kachemak Bay. In 1974 there were a total of 138 king crab vessel registrations in the Cook Inlet area. Of these,76 vessels landed 1.6 million

Table 7.

Kachemak Bay

King Crab Landing, by Month, in Pounds

1960-1966

Month	1960	1961	1962	1963	1964	1965	1966
January	336,917	237,660	131,304	114,941	105,657	149,128	51,935
February	997,617	544,190	238,135	515,029	192,473	52,243	272,776
March	475,197	221,137	494,653	91,042	238,594	512,206	332,233
April	425,820	266,240	162,820	18,994	43,655	118,246	236,820
May	648,515	389,287	135,833	316,078	55,360	111,923	5,879
June	298,768	622,736	85,350	526,617	246,200	97,291	113,731
July	545,863	530,088	150,469	459,757	630,416	330,877	426,599
August	439,518	171,097	258,023	153,320	333,045	414,190	331,370
September	10,641	7,025	42,879	167,791	80,001	66,107	78,983
October	3,856	856	182,187	42,169	71,247	694	5,225
November	663	14,430	43,771	6,763	7,003	9,137	6,764
December	56,400	27,670	43,556	78,028	29,269	17,911	48,049
TOTALS	4,239,775	3,032,416	1,968,980	2,490,529	2,032,920	1,879,953	1,910,364

pounds from Kachemak Bay. From January 1 through mid-March in 1975 a total of 668 thousand pounds of king crab were caught in the bay. The season was scheduled to reopen on August 1, however, due to a fishermen's strike there has been no fishing as of late August.

Tables 7 through 10 contain catch and biological data collected from the Kachemak Bay commercial king crab fishery.

Table 7. cont.

Kachemak Bay

King Crab Landing, by Month, in Pounds

1967-1974

Month	1967	1968	1969	1970	1971	1972	1973	1974
January	20,456	14,725	23,913	36,697	107,782	359,169	93,459	123,479
February	134,217	222,196	88,927	238,850	127,456	343,560	308,347	152,084
March	282,286	115,693			79,039	352,631	150,254	134,651
April	71,499	5,840						
May	6,467							
June						5,682		
July	412,588							
August	298,523	477,168	597,235	1,016,501	552,378	404,416	1,102,211	671,381
September	29,174	98,507	459,065	153,925	160,163	117,351	193,788	324,135
October	11,503	8,764	93,751	12,876	39,836	18,174	61,477	51,653
November	3,605	20,908		14,566	35,109	97,707	110,909	49,672
December	9,390	32,719	39,663	27,873	149,379	201,316	94,396	102,475
TOTALS	1,279,708	996,520	1,302,554	1,501,288	1,251,142	1,900,006	2,114,841	1,609,530

Table 8. Kachemak Bay king crab landings; 1960-1974.

Year	Landings	Crab	Crab Per Landing
1960	2,434	455,000	187
1961	2,619	364,045	139
1962	1,843	296,123	160
1963	1,435	347,096	241
1964	1,019	299,165	225
1965	742	217,544	293
1966	681	226,557	332
1967	705	164,335	233
1968	659	128,720	195
1969	681	196,350	288
1970	700	206,471	295
1971	857	153,856	179
1972	1,011	238,092	236
1973	1,070	284,543	266
1974	1,175	223,454	190
TOTAL	17,631	3,731,351	3,459
15 Year Average	1,175	248,757	231

Table 9. Comparative measurements of king crab carapace lengths in percent for winter and summer commercial caught crab in Kachemak Bay.

KACHEMAK BAY

WINTER

Carapace Size Range	1962	1963	1966	1970	1971	1972	1973	1974	1975	Ave.
140–159 mm	4	21	16	33	20	11	31	35	5	20
160–179 mm	59	52	65	56	68	69	52	55	63	60
180+ mm	37	27	19	11	12	20	17	10	32	20

SUMMER

Carapace Size Range	1963	1968	1969	1970	1971	1972	1973	1974	Ave.
140–159 mm	69	58	65	65	40	56	60	58	59
160–179 mm	28	38	32	34	52	38	34	39	36
180+ mm	3	4	4	1	8	6	6	4	5

Table 10. Average weight of king crab for Kachemak Bay, Cook Inlet, 1960-1974.

YEAR	KACHEMAK BAY AVERAGE WEIGHT
1960	9.2
1961	8.5
1962	8.2
1963	8.1
1964	7.9
1965	8.2
1966	8.5
1967	7.9
1968	8.3
1969	7.2
1970	7.2
1971	8.0
1972	8.0
1973	7.3
1974	7.7
Average	8.0

Tanner Crab

Tanner crab were first harvested commercially in Cook Inlet in 1968 when 165 thousand pounds were taken in Kachemak Bay. The fishery has expanded rapidly since then and tanners are now harvested throughout lower Cook Inlet. Tanner crab appear to be more ubiquitous and abundant than any other commercial shellfish species in the lower Cook Inlet area.

The commercial catch of tanner crab in Kachemak Bay from 1968 through 1974 has averaged 1.7 million pounds. The peak year of production occurred in 1973 when 3,763,060 pounds were landed. A total of 80 vessels landed tanner crab from Cook Inlet waters in 1973 and most of these vessels fished Kachemak Bay during the peak of the season.

There was a decline in the Kachemak Bay tanner catch during 1974 as only 1.1 million pounds of tanners were landed. The poor catch was attributed partially to less effort and also a general decline in the stock. The 1975 catch through June was 936 thousand pounds and this low catch can be attributed largely to a lack of effort due to poor market conditions. The 1973 catch was probably above the rate the bay is capable of producing on a sustained basis. The Board of Fish and Game established a 3.0 million pound quota for Kachemak Bay in 1974. The tanner crab season was also reduced and is presently set from December 1 through June 15. The closure was established to protect tanners during their molting, reproductive, and soft shell periods.

Table 11 shows the tanner crab catch, by month in Kachemak Bay since 1968 and Figure 39 shows the size distribution in the commercial catch from 1970 through 1974.

Table 11.

Kachemak Bay

Tanner Crab Landing, by Month, in Pounds
1962-1974

Month	1962	1968	1969	1970	1971	1972	1973	1974
January			38,893	51,789	26,545	81,104	223,061	210,684
February		2,515	115,496	156,672	107,832	163,554	550,652	95,014
March		8,613	298,678	289,044	227,506	642,638	747,590	222,613
April		35,215	474,234	362,576	358,024	593,642	558,530	325,896
May	3,404	80,070	161,753	256,017	231,751	618,143	336,687	222,779
June		5,420	288,752	21,824	82,357	272,748	229,504	
July			41,950		3,024	9,527	144	
August		608				1,688		
September		490			728	3,226	60	
October		1,570	7,692	1,304	602	13,645		
November		1,514		595	56,992	252,529	829,119	
December		10,476	9,232	12,788	91,127	289,638	287,713	29,277
TOTALS	3,404	146,491	1,436,680	1,152,609	1,186,488	2,942,082	3,763,060	1,106,263

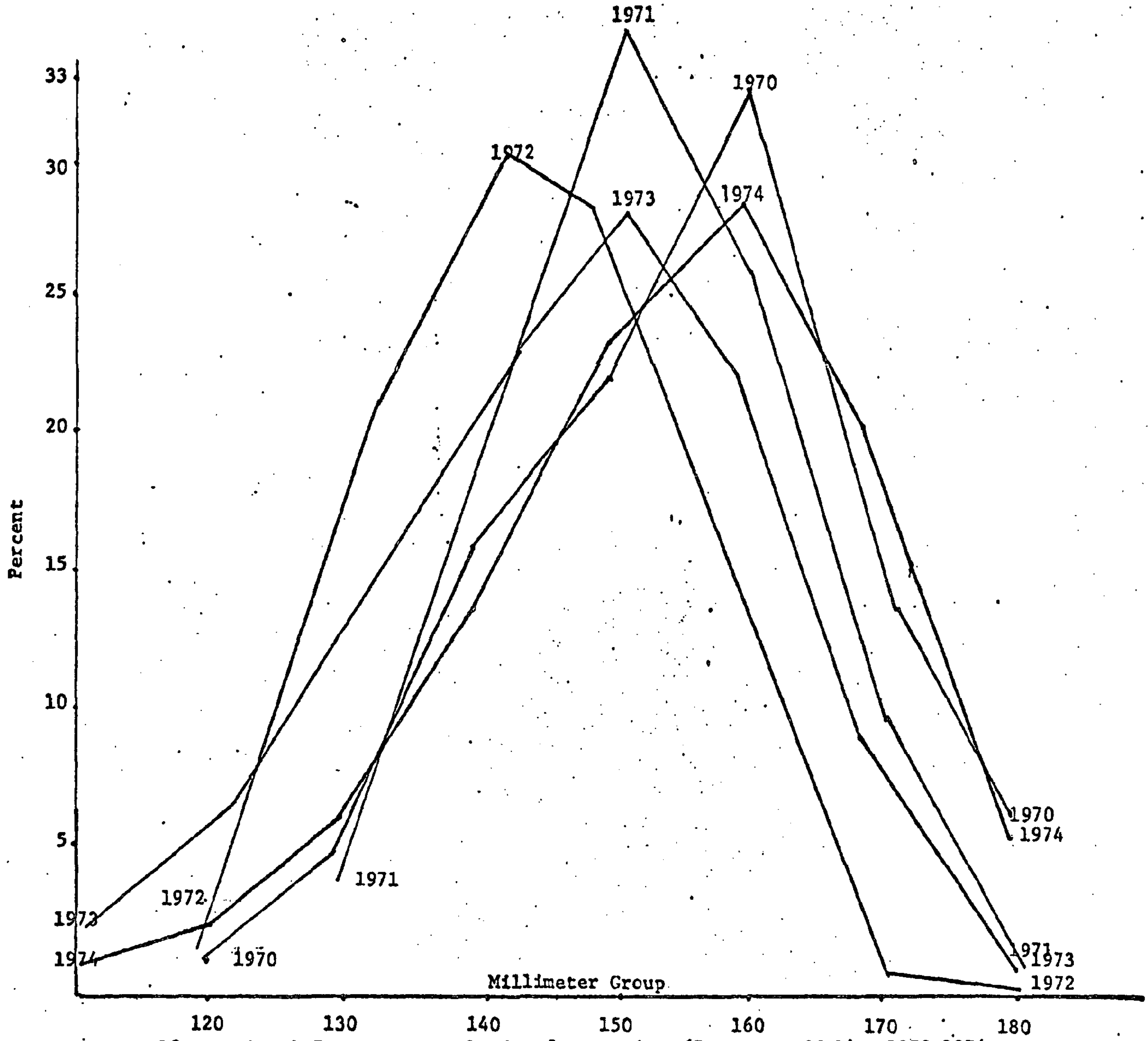


Figure 39. Kachemak Bay tanner crab size frequencies. (Carapace width). 1970-1974.

Juveniles

Dungeness Crab

The dungeness crab commercial fishery started on a sustained basis in Kachemak Bay in 1961 after some sporatic attempts in the 1950's. Ten boats fished out of Seldovia and Homer in 1961 and all processing was aboard a floating cannery anchored in Halibut Cove. The primary months fished were during October and November and a total of 191 thousand pounds were taken mostly from above the Homer Spit. In 1962 processing was conducted in Seldovia as well as Halibut Cove and 460 thousand pounds were landed from Kachemak Bay. The peak year of production occurred in 1963 when 1.7 million pounds were landed from the bay. In 1964 a total of 400 thousand pounds were taken and then during the next three years (65-67) the fishery fell off drastically due to a lack of processing facilities following the 64 earthquake and a declining market.

In 1968 a processing plant was opened in Homer (Alioto Fish Company) and 378 thousand pounds were taken from the bay, most of this production from four boats. Since 1969 the dungeness fishery has been sporadic in Kachemak Bay with an average annual yield of 235 thousand pounds. The highest year of production since 1964 was in 1974 when 721 thousand pounds were landed from the bay. A total of 36 vessels participated in the 1974 fishery and made a total of 609 landings. The bulk of the catch was made in the Bluff Point area between July and November.

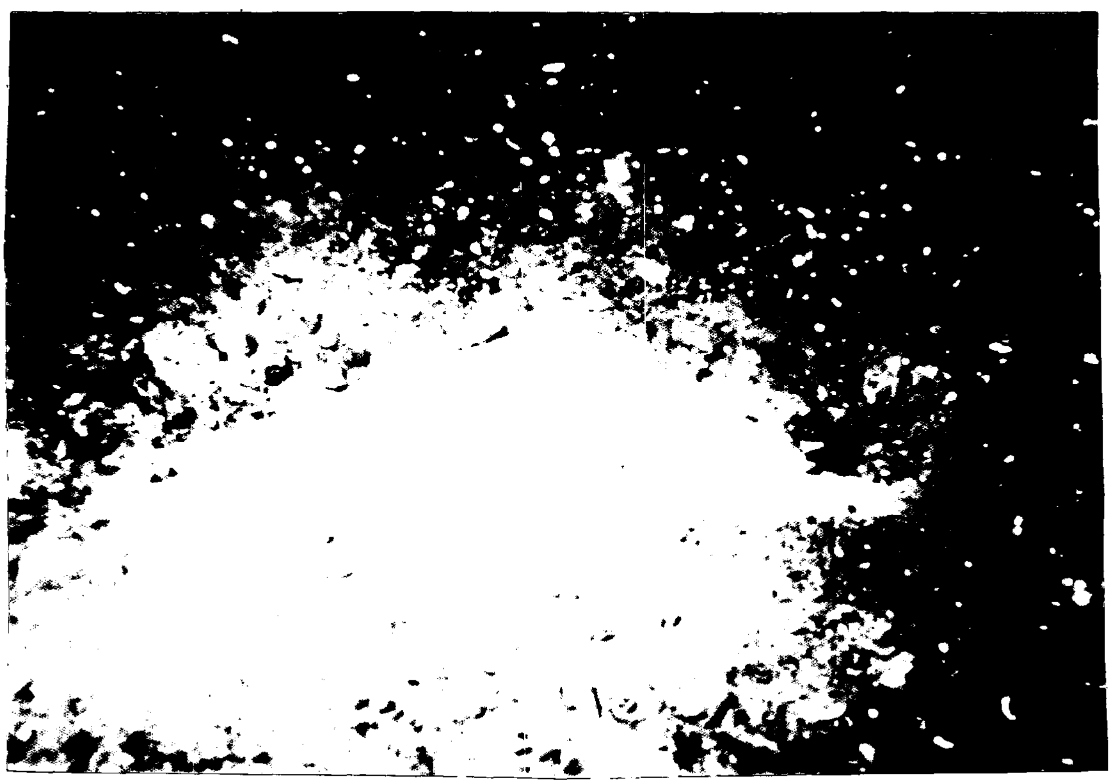
Dungeness crab landings by month for Kachemak Bay from 1961 through 1974 appear in Table 12.

Table 12. Kachemak Bay dungeness crab catch by month, 1961-1974.

Month	1961	1962	1963	1964	1965	1966	1967	1968	1969
January	699		3,379	1,492					488
February		10,090	609	170					25
March			37,240	1,984					335
April	290		36,165	3,004					1,346
May	664	1,963	226,922	17,672	466	2,836	1,776		1,833
June	442	11,502	262,645	66,979	11,029	7,651	1,471		3,987
July		30,167	291,664	62,587	13,389			84,480	13,898
August		67,811	247,915	73,807	7,607			182,393	14,876
September		165,407	271,376	118,709	27,192	1,183	90	120,240	13,106
October	54,965	188,317	258,062	64,346	9,318		3,831	66,841	
November	136,623	21,868	24,665	6,255	4,008	853		30,482	
December		6,645	4,957		1,202			16	
TOTALS	193,683	503,770	1,665,599	417,005	74,211	12,523	7,168	484,452	49,894

Table 12 continued. Kachemak Bay dungeness crab catch by month, 1961-1974.

Month	1970	1971	1972	1973	1974
January			60	3,555	3,899
February			1,620	615	975
March	115	[illegible]	36	158	2,969
April				4,032	468
May		1,745		11,429	5,374
June	7,889	11,271	1,715	12,742	16,185
July	15,009	21,818	5,336	7,861	110,855
August	37,597	17,049	3,568	8,224	217,570
September	95,571	20,287	5,085	36,069	201,839
October	52,265	15,951	4,517	147,502	98,803
November	1,373	7,221	7,031	68,203	43,781
December		1,819	9,962	8,387	4,192
TOTALS	209,819	97,161	38,930	308,777	706,910



Cancer Magister at home

Trawl Shrimp

The first attempt at establishment of a permanent shrimp fishery in Kachemak Bay occurred in 1959 when two processing facilities were established in Seldovia. Records are not available separating the Kachemak Bay shrimp catch from the remainder of the Cook Inlet Management area for the first three years of the fishery (1959-1961), however, 5.2 million pounds were taken during this time period and indications are that most of this catch was from Kachemak Bay with smaller catches coming from Nuka Bay, Resurrection Bay, and Day Harbor. From 1962 through 1964 the average shrimp harvest from Kachemak Bay was 800 thousand pounds. From 1965 through 1968 the fishery suffered from poor market conditions and lack of processing facilities in the area. The average catch during this period was 276 thousand pounds.

The Kachemak Bay shrimp fishery began to stabilize in 1969 when a new processing plant owned by Alaskan Seafoods went into operation at the end of the Homer Spit. Two boats participated in the fishery in 1969 and 1.8 million pounds of shrimp were landed from the bay. The trawl shrimp catch from 1970 through 1974 averaged 5.2 million pounds for the Bay.

The trawl shrimp season presently runs from June 1 through March 31. At present, the waters of Kachemak Bay inside a line from Anchor Point to Point Pogibski are on two guideline harvest level periods, June 1 - October 31 and November 1 - March 31, of 2.5 million pounds each for a total quota of 5.0 million pounds.

The trawl shrimp catch from Kachemak Bay by month since 1969 appears in Table 13. Since 1969 a log book program has been maintained on the Kachemak Bay shrimp trawl fishery and catch per unit of effort (C.P.U.E.) data from this program appears in Table 14. It is interesting to note that since 1969 there has been no decline in C.P.U.E. observed, in fact there has been a general increase during the last few years indicating a very healthy stock.

Table 13. Shrimp trawl catches by month for Kachemak Bay, 1969-1975.*

Month	1969	1970	1971	1972	1973	1974	1975 *	average
January	1,130	215,036	102,836	405,730	450,873	1,209,366	582,535	494,396
February	3,274	448,856	446,136	641,653	443,266	156,524	572,648	451,514
March	1,870	494,894	979,136	170,868	102,614	328,332	506,505	430,392
April	11,927	550,731	466,265	77,133	49,625			285,939
May	4,661	338,599	160,617	77,318				192,178
June	104,026	665,715	434,045	539,482	615,078	437,331		538,330
July	158,178	852,126	484,362	544,454	1,086,344	1,613,168		716,091
August	249,924	767,600	590,623	569,364	727,595	478,953		626,827
September	345,296	603,127	624,752	471,921	73,137	789,933		512,574
October	432,848	324,360	488,492	651,547		193,139		414,385
November	219,791	386,357	457,822	618,781	431,023	431,827		465,162
December	314,227	77,287	160,030	608,930	570,249	424,901		368,279
Totals	1,847,152	5,724,688	5,395,116	5,377,181	4,549,804	5,063,474	1,661,688	5,496,067

* Preliminary data.

Table 14. Trawl shrimp catches in pounds per drag hour for two vessels in Kachemak Bay, 1969-1975 1/.

		West of Spit		East of Spit	
		A	B	A	B
1969	July	2243	1795		
	Aug.	1523	2440	660	862
	Sept.	3651			
	Oct.	3630		2321	1964
	Nov.			1863	1695
	Dec.			2543	2046
1970	Jan.			2897	2672
	Feb.			2798	2769
	Mar.			2733	3017
	April	2581	2440	1903	2078
	May	2811	2207		
	June	1562	1216		
	July	2289	1837		
	Aug.	2253	1730		
	Sept.	2281	2048		
	Oct.	2580	2198	1619	1740
	Nov.	3338	2547	1272	1309
	Dec.		1396	1585	1167
1971	Jan.	4015	1651	1101	1112
	Feb.	4187	3446	3050	
	Mar.	7409	10850		
	April	1888	2630		
	May	1516	1727		
	June	1462	1151		
	July	813	821	715	
	Aug.	2097	2320	839	
	Sept.	3658	2811		
	Oct.	3114	2728		
	Nov.	2692	2844		
	Dec.	2959	2938		
1972	Jan.	5801	4709		
	Feb.	4861	5763		
	Mar.	12279	8295		
	April	3150	2940		
	May	2756	1923		
	June	2182	5346		
	July	1694	1688		
	Aug.	2757	3259		
	Sept.	4772	4281		
	Oct.	4580	4765		
	Nov.	2616	3531		
	Dec.	2917	2842		

		West of Spit	
		A	B
1973	Jan.	3027	2193
	Feb.	3996	4710
	Mar.	Closed	--
	April	Closed	--
	May	Closed	--
	June	3126	2115
	July	3088	2859
	Aug.	3876	3541
	Sept.	5882	4113
	Oct.	Closed	--
	Nov.	4331	4470
	Dec.	6234	6049
1974	Jan.	6157	5179
	Feb.	11641	12150
	Mar.	15558	22193
	April	Closed	--
	May	Closed	--
	June	3579	2489
	July	3150	2669
	Aug.	2760	2902
	Sept.	5374	5591
	Oct.	4151	4993
	Nov.	5047	5179
	Dec.	6572	6504
1975	Jan.	6440	5999
	Feb.	5708	5651
	Mar.	9039	8276

1/ These two vessels have been in the fishery the longest and are used as indicators in changes in CPUE.

The average C.P.U.E. for the Kachemak Bay trawl shrimp fishery is the highest in the state, surpassing even the most productive areas in the Kodiak region. It is also higher than the Gulf of Mexico and the Gulf of Maine where major trawl fisheries on shrimp also occur. The C.P.U.E. in the Kachemak Bay trawl fishery is probably the highest in the United States and may be the highest in the world.

Table 15 and Figures 40 and 41 provide or depict an index of the species composition of the commercial trawl catch between May of 1970, when sampling of the commercial catch began, through September of 1973. As can be seen from Table 15 and Figure 40 pink shrimp dominate catches (57.1%) followed by humpy shrimp (36.3%). Coonstripe and sidestripe shrimp make up a relatively small percent of the trawl catch. 1974-1975 data which is presently being worked up will show a similar composition. There are annual differences in species composition of commercial catches as well as variations between months. More information on the biology of the shrimp will appear in the research section of this report.

Table 15. Average species composition of the commercial trawl catch from Kachemak Bay - May 1970 through September 1973.[1]

Percent by Species

Month	P. Borealis Pink	P. goniurus Humpy	P. hypcinotus Coonstripe	P. dispar Sidestripe
Jan.	69.7	17.2	11.5	1.7
Feb.	55.3	20.9	7.5	16.3
Mar.	34.5	58.5	3.5	3.5
Apr.	72.5	24.0	1.0	2.5
May	61.1	38.5	0.2	0.3
Jun.	71.9	23.7	3.0	1.4
Jul.	56.4	41.0	1.5	1.1
Aug.	48.2	50.0	1.2	0.6
Sep.	41.6	57.4	1.1	0.1
Oct.	51.2	47.3	0.7	0.8
Nov.	62.5	22.6	6.9	8.0
Dec.	60.0	34.0	2.0	4.0
Mean	57.1	36.3	4.0	3.4

[1] Data based on weekly random samples of the commercial catch.

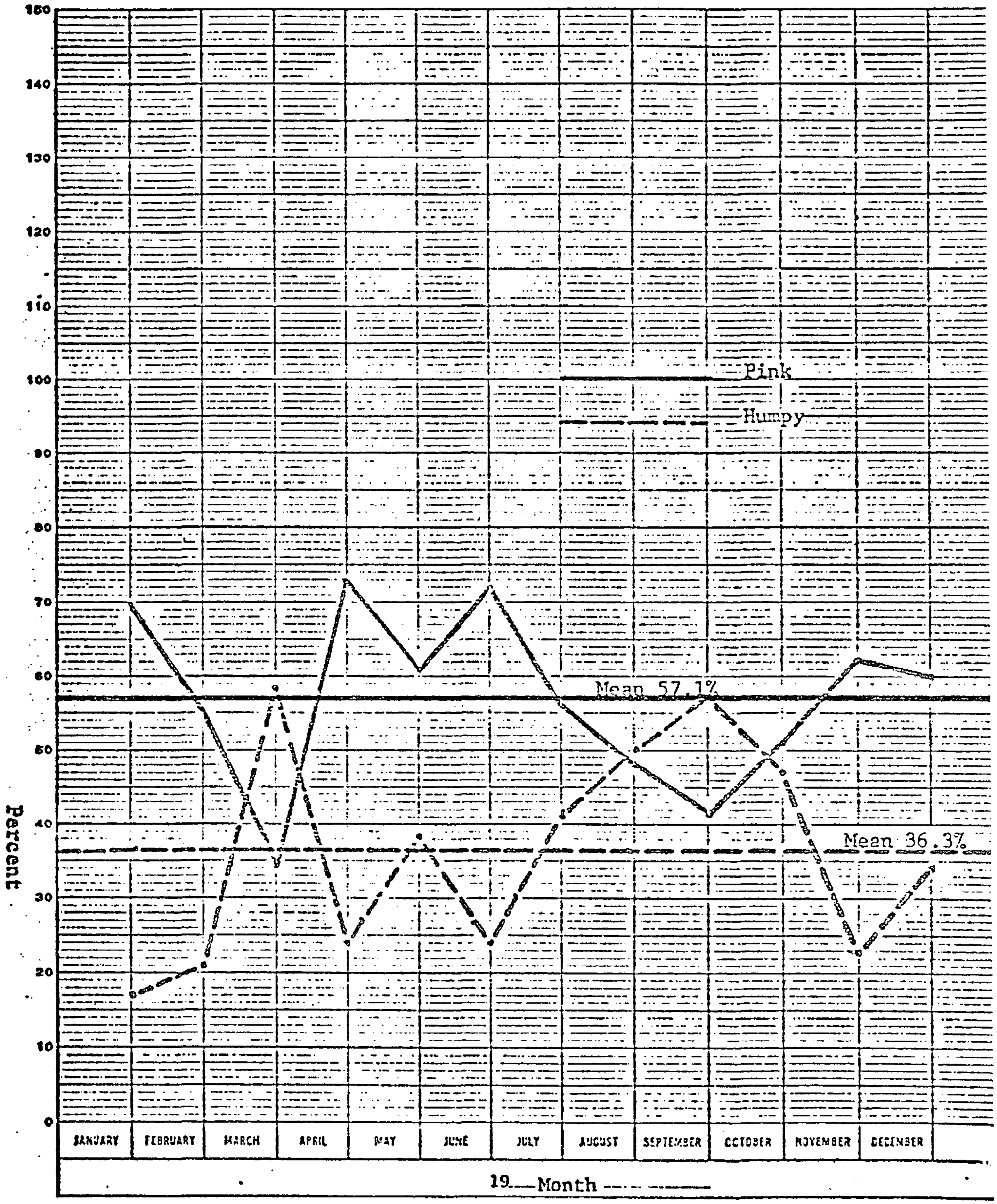


Figure 40. Average monthly commercial trawl catch of pink and humpy shrimp Kachemak Bay, May 1970 through September 1973.

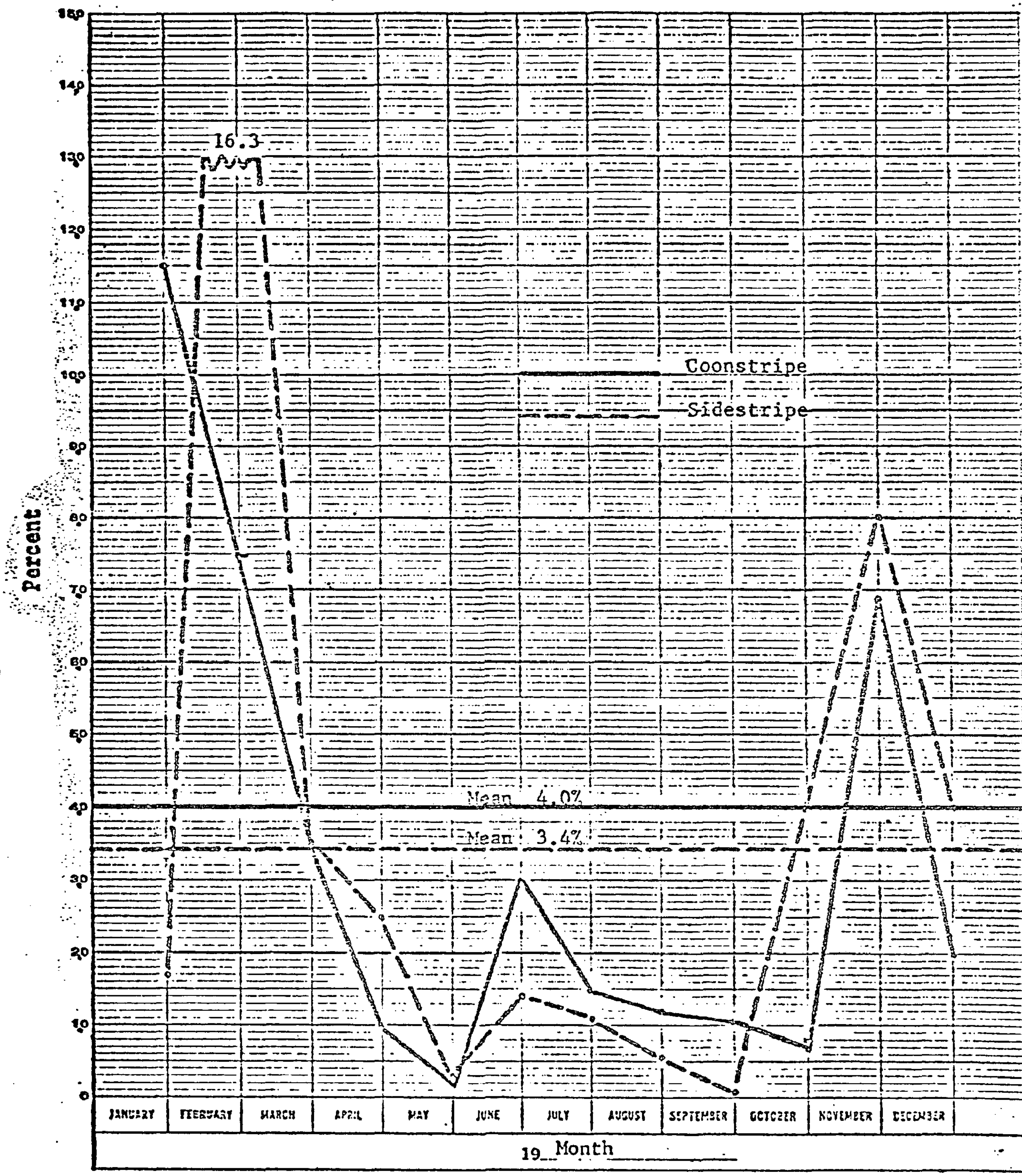


Figure 41. Average monthly commercial trawl catch of coonstripe and sidestripe shrimp, Kachemak Bay, May 1970 through September 1973

Pot Shrimp

There is also a pot shrimp fishery in Kachemak Bay. This fishery did not start up on a significant basis until 1971 when 55,665 pounds were landed. The 1974 catch of 678,097 pounds was the highest on record and the fishery presently appears to be in a very healthy state. A slight increase occurred in the number of vessels participating in the fishery from 41 in 1973 to 46 in 1974. The number of landings made was 1,249, a 65 percent increase from 1973.

A good abundance of pot shrimp, which are over 90 percent coonstripes, and a fairly steady market and increased effort have caused the significant increase in catches during the past two years.

A sampling program has been initiated to monitor the pot shrimp fishery. Sampling will determine species and age class composition of the catch as well as the area being fished. An attempt will be made to determine C.P.U.E. in pounds per pot.

Table 16 shows the Kachemak Bay pot shrimp catches by month from 1971 through 1974. There is presently a 600,000 pound quota on pot caught shrimp in Kachemak Bay.

Table 16. Kachemak Bay Pot Shrimp catches, 1971-1974.

Month	1971	1972	1973	1974
January		1,494	13,883	60,793
February		1,463	35,235	47,955
March		11,764	18,634	203,161
April	960	6,434	32,115	259,209
May	3,680	7,257	22,081	28,065
June	2,872	23,063	20,239	15,423
July	260	24,191	11,946	15,517
August	4,945	11,752	20,036	8,600
September	759	16,241	10,960	5,210
October	13,251	3,242	33,738	8,067
November	26,720	29,288	66,864	10,898
December	2,218	29,752	38,380	15,180
Total	55,665	165,941	324,111	678,078

Kachemak Bay Renewable Wealth

Herring

Pacific herring have undergone two periods of exploitation in Kachemak Bay. The first period was from 1914 through 1928 when a saltery fishery was centered in the Halibut Cove area. A total of nearly 90 million pounds of herring were harvested during this time period (Table 17). The second fishery on herring in Kachemak Bay started in 1969 when a sac roe market developed. Since 1969 a total of 7.2 million pounds have been harvested from Kachemak Bay. The peak year was 1970 when 11 vessels landed 5.4 million pounds (Table 18). The herring fishery occurs during May and early June in the Kachemak Bay area and most of the catch comes from the Halibut Cove - Glacier Spit and Mallard Bay areas. (Figure 42). The annual sustained yield is not known at the present time and research into stock status is needed.

Table 17. Kachemak Bay historical herring catch, 1914-1928.

Year	Millions of Pounds	Tons
1914	0.3	150
1915	0.03	15
1916	0.1	50
1917	1.9	950
1918	4.0	2,000
1919	5.3	2,650
1920	1.9	950
1921	5.2	2,600
1922	1.0	500
1923	7.6	3,800
1924	14.1	7,050
1925	19.2	9,600
1926	14.3	7,150
1927	7.2	3,600
1928	4.3	2,150

Table 18. Kachemak Bay herring catches in pounds, 1969 - 1974.

Year	Pounds	Landings	Vessels
1969	1,103,041	41	5
1970	5,417,385	104	11
1971	25,050	4	2
1972	2,046	1	1
1973	407,533	20	12
1974	219,359	19	11

Fig. 42 — Kachemak Bay, major herring spawn and commercial catch zone

Crustacean Larval Biology

In 1971 the NMFS began a comprehensive study of the larvae of king crab and shrimp in Kachemak Bay. In general, the study was designed to determine the distribution, abundance, and survival of larvae. The first requirement of the study was to determine locations in Kachemak Bay where larvae are released and their subsequent dispersal from the releasing areas. Preliminary sampling began in the spring of 1971 to standardize techniques and to verify the expected seasonal occurrence of larval release. Sampling in 1972 was more intensive and designed to determine more precisely the areas of release and the patterns of dispersal of larvae from the releasing areas. The preliminary results of the 1972 studies have recently been received by the Alaska Department of Fish and Game. The following are some excerpts from that report which testify to the critical nature of the Bluff Point area, which was also the major area of interest in the oil and gas lease sale.

The patterns of larval abundance and distribution in Kachemak Bay in 1972 can be summarized as follows: king crab zoea (which is the initial stage larvae after the eggs hatch) were released in Kachemak Bay primarily in the Bluff Point area. Many larvae remained in the release area throughout their planktonic or free floating existence. The remaining larvae were rapidly displaced from the releasing area by tidal action along primarily two routes, one southwestward toward Cook Inlet and the other souteastward toward Tutka Bay and Sadie Cove.

Larvae first occurred in the plankton samples during the latter half of April. The area of greatest abudance occurred in the Bluff Point area. Abundance decreased rapidly on either side of this area. During the latter half of May larvae were distributed throughout Kachemak

Bay. The most obvious feature of larval distribution at this time was the band of highest abundance which extended across the outer bay south of Anchor Point to Seldovia Bay. Abundance decreased rapidly seaward of this band but remained relatively high shoreward throughout most of the inner bay. Both distribution and abundance of larvae continued to change throughout the Bay during the first half of June. Two centers of abundance existed in the outer bay. The first centered around the Bluff Point area and extended as a tail in a southwesterly direction from the Bluff Point area. Another extended as a band of abundance from the Homer Spit southward to Kasitsna Bay. In general, the concentrations of larvae from April through June provide evidence of the location of releasing sites. The initial occurrence and higher abundance of these larvae off Bluff Point indicate that this area is a major releasing area in Kachemak Bay for king crab zoea larvae. This assumption is supported by studies of female king crab by the Alaska Department of Fish and Game. These studies show that egg bearing king crab congregate in this area during spring for the purpose of releasing larvae. Further studies by the NMFS also indicated that the Bluff Point area is a major settling area for king crab larvae.

During the king crab larvae study, notes were also kept on other crustacean larvae such as shrimp and tanner crab. Preliminary information indicates that the area of greatest abundance of these species was also in the Bluff Point area. If so, then the area off Bluff Point is critical for release and subsequent settling of several species of economically important shellfish larvae.

The above summary of the larvae biology and inferred role played by the Bluff Point site in the reproduction and larvae biology is to date the prevelant point of view.

The newly acquired information on the circulation of Kachemak Bay, together with some preliminary estimate of the residence time of a water parcel as it swings through the system, does not quite tally with the assumption that the larvae will tend to remain and settle in the Bluff Point area and/or would be redistributed southwards towards the south shore.

Fig. 43 illustrates the more recurrent transport pattern as derived from the drogues trajectories. Preliminary analysis of the drogue data indicates that the two gyres seem to remain somewhat south of an east-west line drawn across the tip of Homer Spit. Much of the crab sanctuary area appears to lie mostly across the path of a rather steady net outgoing flow. That the Bluff Point area is a center for the spawning of king crab is already documented. What happens to the larvae spawned in the area is, based upon the present preliminary results of the drift studies open to speculation.

Perhaps, to best relate the knowledge gained from the circulation studies with the larval life history of the various crustacean known to spawn in Kachemak Bay, one should refer to the diagram of Fig. 44. The diagram shows the length of time through which crustacean larvae will be observed in the plankton. Major spawning periods for the various species are indicated.

Developing king crab larvae will be planktonic for about 30 to 40 days, Tanner crab larvae for about 60 days, dungeness crabs are for the present unknown, and pandlid shrimps for about 60 days.

Based upon the present preliminary estimate for a water parcel residence time within the Bay, most of the larvae spawned in the Bay ought to be transported out of the Bay before they have reached the settling stage.

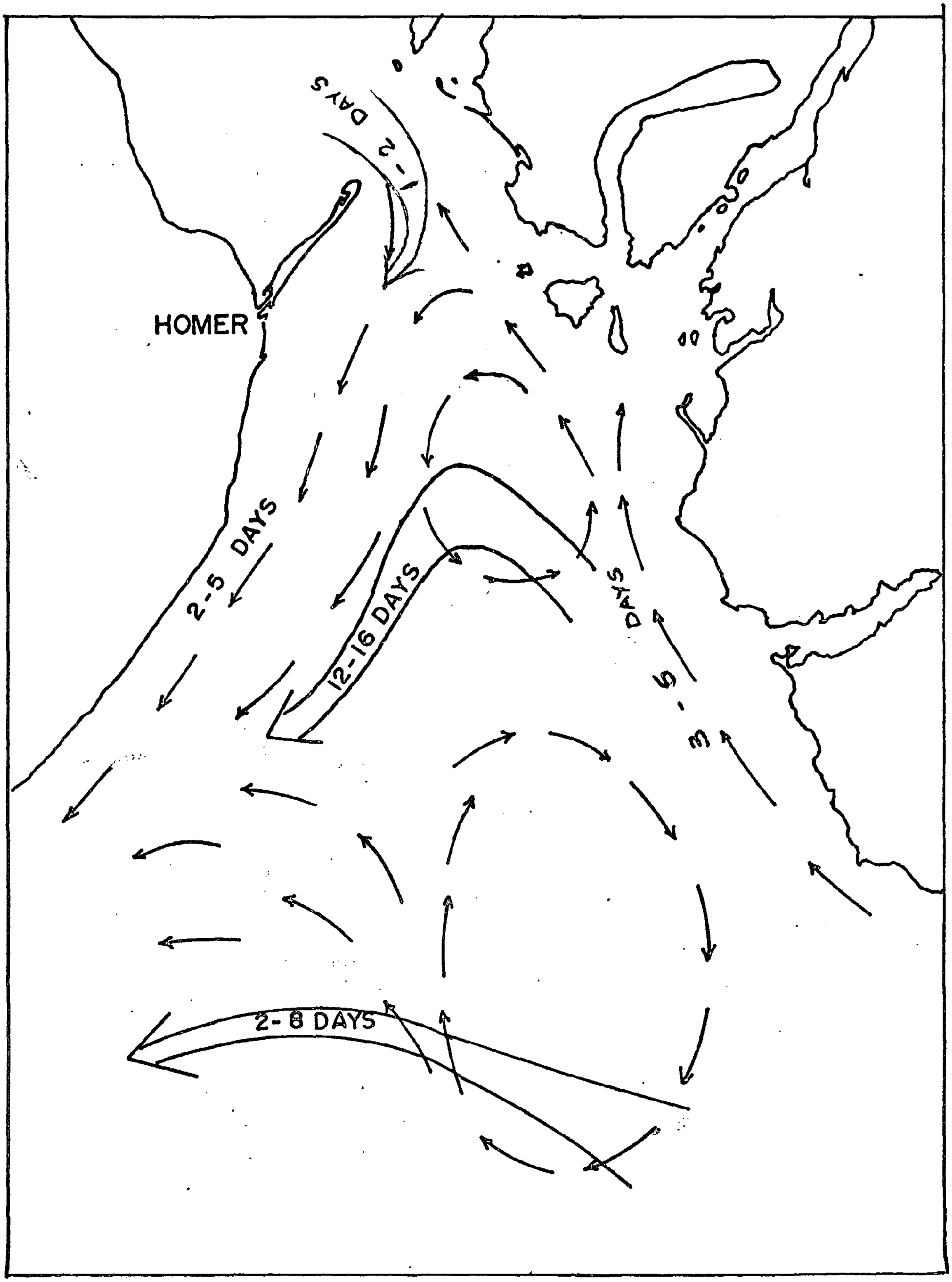


Fig. 43 - NET TRANSPORT VELOCITIES THROUGH KACHEMAK BAY AS DERIVED FROM DROGUE DATA

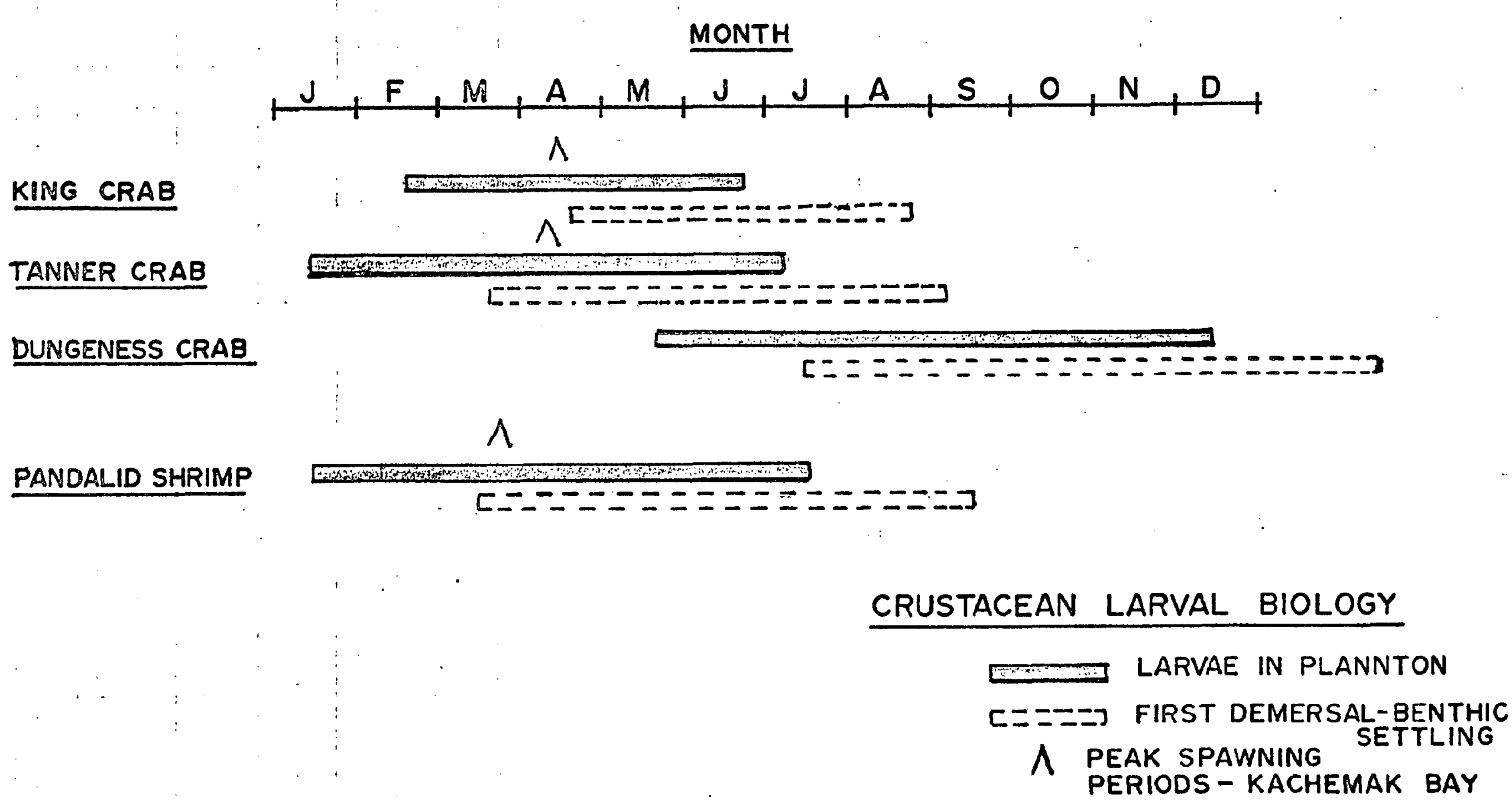


Fig. 44 - Planktonic Occurence of Crustacean Larvae

Various unpublished data report by Haynes (NMFS Lab. Kasistna Bay) and others discuss recent observations on various phases of larval biology. The following insert summarizes their findings.

Careful analysis of the material of indicates that our present understanding of various stages of larvae development in Kachemak Bay is very incomplete. Observations are obtained at a network of fixed stations, but no one can give any assurances that the same population is being repeatedly sampled. The nature of the circulation indicate that Kachemak Bay is an input-output system, suggesting that much of the larvae sampled at any one given time might have been spawned outside the Bay.

Work is presently underway to reevaluate all basic data in terms of new knowledge on transport mechanism being gathered by the long term drift measurements program.

Preliminary results of larval distribution, abundance, and survival studies in Kachemak Bay, 1972 (Abstract)

KING CRAB ZOEA

Plankton tows were made semi-monthly in Kachemak Bay beginning the latter half of March and extending through June, 1972. Preliminary sampling in 1971 had indicated that king crab zoea occurred in the bay during these months. Samples were collected using the National Marine Fisheries Service research vessel R/V Sablefish except during the latter half of May when a few plankton tows were made with the University of Washington's research vessel R/V Commando. Sampling terminated at the end of June unintentionally; zoea were still present in the water at that time.

The station pattern consisted of 24 stations distributed somewhat evenly over an area of about 688 kilometers (428 square miles) (Figure 45). Not all stations were occupied during each semi-monthly period due to inclement weather especially at the beginning of the sampling season.

Plankton tows were made with Miller High-Speed samplers (Miller, 1961). Nets of #0 mesh were used throughout the study.

Zoea first occurred in the plankton samples during the latter half of April. Area of greatest abundance occurred as a band extending seaward from off Bluff Point to station 17. Abundance decreased rapidly on either side of this band.

During the first half of May, zoea abundance increased markedly in the outer bay. Greatest abundance occurred in the northern half of the outer bay

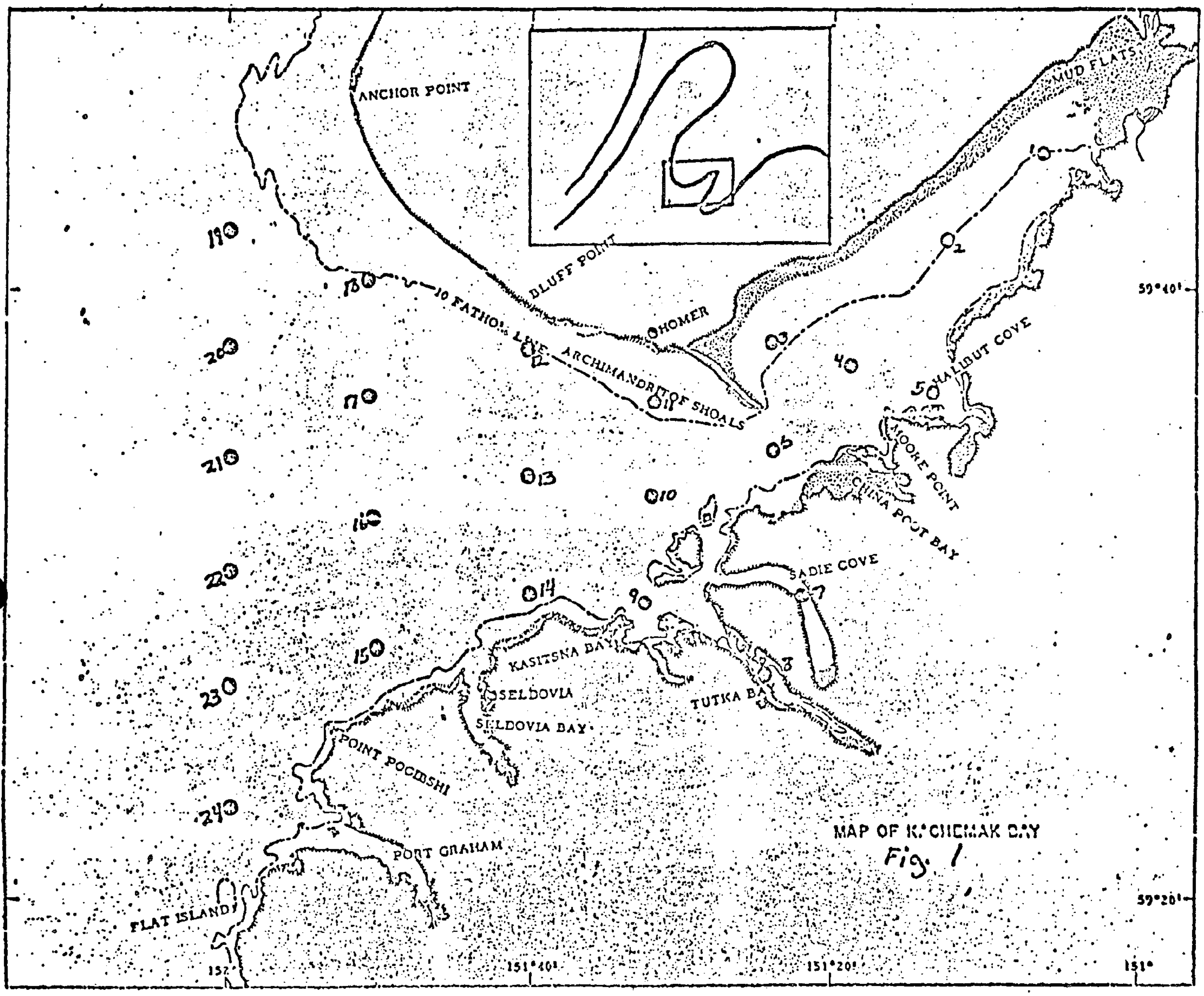


Fig. 45. NMFS Sampling Stations for Zoea Larvae

and was centered at station 17. Dispersal of abundance extended from the center eastward to Homer Spit and then southeastward to China Poot. Lower levels of abundance were found throughout the remainder of the outer bay and at the entrance to the inner bay. A few zoeae were also caught at the head of the bay (station 1). No zoeae were caught during this sampling period in either Tutka Bay or Sadie Cove.

During the latter half of May, zoeae were caught at all stations except one (station 21) but abundance remained highest in the outer bay. The most obvious feature of zoeal distribution at this time was the band of highest abundance that extended across the outer bay from south of Anchor Point to Seldovia Bay. Abundance decreased rapidly seaward of this band but remained relatively high shoreward and throughout most of the inner bay.

Both distribution and abundance of zoeae continued to change throughout the bay during the first half of June. Two centers of abundance existed in the outer bay, one that included stations 16 and 17 (in the center of the bay) and extended as a tail in a southwesterly direction to include station 24 and another that extended as a band of abundance from Homer Spit southward to Kasitsna Bay. High abundance occurred between these two areas, in Sadie Cove and in the inner bay. Zoeal abundance along the outer transect of stations was again low except at stations 23 and 24 where high abundance reflected the dispersal of zoeae from stations 16 and 17.

A striking change in zoeal distribution and abundance occurred during the latter half of June in the northern portion of the outer bay between Anchor Point and Homer Spit. In this area, zoeal abundance had increased markedly, particularly at stations 12, 13, 17, and 18. Catches of zoeae throughout the remainder of the outer bay, although still high, had decreased from the previous sampling period, especially along the southern shore.

In general, concentrations of stage 1 larvae provide evidence of the location of releasing sites. In this study, the zoeae caught during April and nearly all those caught during the first half of May were stage 1. The initial occurrence and high abundance of these zoeae off Bluff Point indicate that this area is the major releasing area in Kachemak Bay for king crab zoeae. This assumption is supported by studies of female king crab in Kachemak Bay by the State of Alaska Department of Fish and Game. These studies show that egg bearing king crab congregate in this area during spring for the purpose of releasing zoeae.

The patterns of zoeal abundance and distribution in Kachemak Bay in 1972 can be summarized as follows. King crab zoeae were released in Kachemak Bay primarily in an area that extended from Bluff Point seaward to at least the location of station 17. Many zoeae remained in the releasing area, expecially in the vicinity of stations 16 and 17, throughout their planktonic existence. The remaining zoeae were distributed rapidly from the releasing area by tidal action along primarily two routes, one southwestward toward Cook Inlet, the other southeastward toward Tutka Bay and Sadie Cove. A large number of late stage zoeae were carried into the bay along the northern shore during the latter half of June. Settling of glaucothoe likely occurred throughout the bay but primarily in the outer bay in the vicinity of the releasing area. Figure 46 shows the king crab larval periods by stage in Kachemak Bay from April 15 to June 30, 1972. Tables 1, 2, and 3 show estimates of king crab zoeae released, estimates of mortality, and estimates of survival in Kachemak Bay based on data collected during the study.

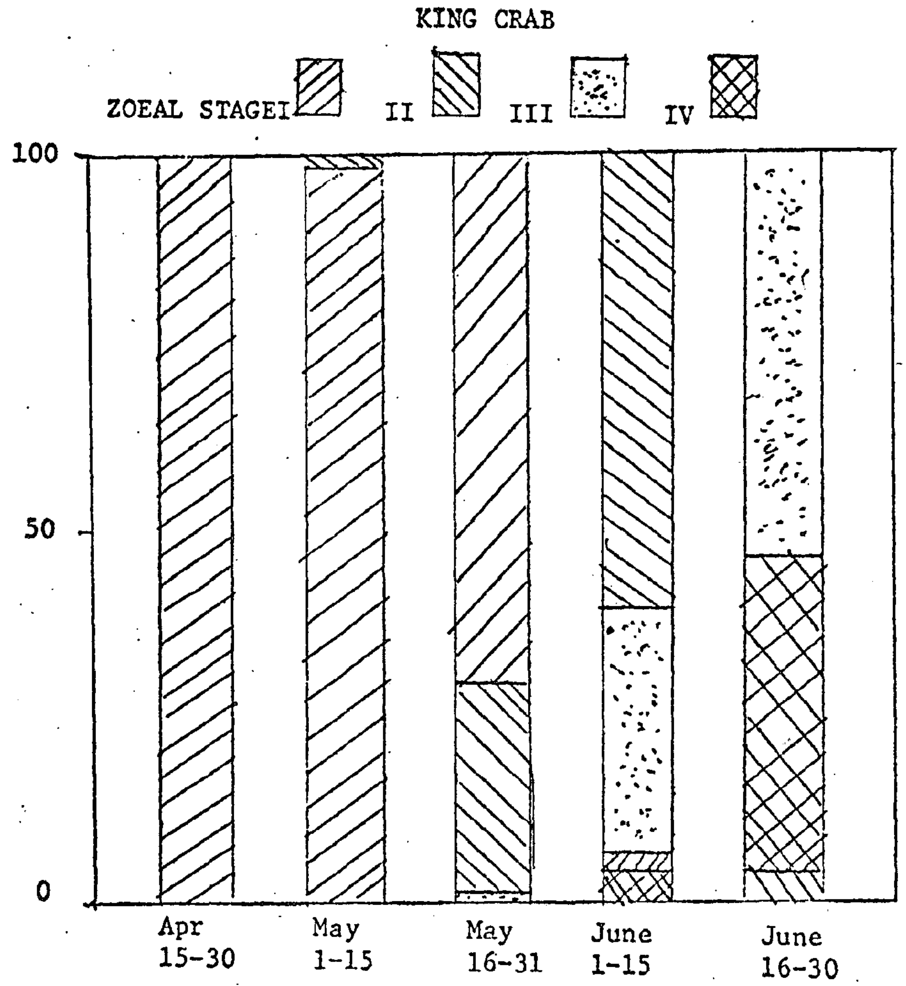


Fig. 46. Kachemak Bay king crab larval periods, 1972.

Table 19 Estimates of total abundance of king crab zoeae (x 10^9) for each semi-monthly sampling period in Kachemak Bay, Alaska, March-June, 1972.

Sampling period	Zoeal stage I	II	III	IV
Mar. 15-31	0	0	0	0
Apr. 1-15	0	0	0	0
Apr. 16-30	8.85	0	0	0
May 1-15	128.59	2.34	0	0
May 16-31	331.85	135.80	3.59	0
June 1-15	38.16	331.78	252.34	27.16
June 16-30	0	7.66	91.01	135.25
	507.45	477.58	347.01	162.41

X 10^9

Table 20 Estimates of instantaneous mortality (i) and seasonal survival (s) rates for king crab zoeal stages I, II, and III collected in Kachemak Bay, Alaska, 1972.

Larval stages	i	s
I-II	0.0607	0.9411
II-III	0.3193	0.7266
III-IV	0.7594	0.4680

Table 21 Estimates of survival of king crab zoeae per 100,000 individuals released in Kachemak Bay, Alaska, 1972. (* estimates probably greatly underestimated).

Larval stage	Duration between stages (days)	Estimated abundance (x 10^9)	Survival per 100,000 zoeae released
I		507.45	----
	18.8		
II		477.58	94,110
	37.0		
III		347.01	72,660*
	54.8		
IV		162.41	68,380*

BRACHYURA ZOEAE

Zoeae first occurred in the samples in the latter half of April but only in insignificant numbers.

Numbers of zoeae increased during the first half of May, but only slightly - greatest number of zoeae at any one station was only 22. During the latter half of May abundance of zoeae increased markedly. Greatest abundance occurred in a band of zoeae that extended from station 17 to Homer Spit. The remainder of the Kachemak Bay had intermediate abundance of zoeae (10-100 zoeae per station) except the outermost area of the bay where abundance was lowest (1-10 zoeae per station).

The band of greatest abundance found during the latter half of May persisted throughout the first half of June and consisted of at least a five-fold increase in zoeae. Zoeal abundance in the remainder of the outer bay was high, including the outermost stations. The inner bay had a relatively low level of abundance (10-100 zoeae per station).

Zoeal abundance was high throughout the outer bay but conspicuously so at station 17 during the latter half of June. Samples for the inner bay for the latter half of June were not processed due to lack of time and the assumption, based upon prior sampling, that zoeal abundance was low.

The above pattern of Brachyuran zoeal abundance is strikingly similar to that of king crab and Pandalid shrimp zoeae from the same sampling period. The most noteworthy feature for all three groups of zoeae is that zoeal abundance originates and remains consistently high in the vicinity of station 17. Also, zoeal abundance of all three groups was consistently greater in the outer bay than the inner bay. Apparently the inner bay is not a major nursery area for these forms as originally supposed.

PANDALID ZOEAE

Pandalid zoeae were first caught in 1972 during the first half of April at station 17 and 13 (Figure I). During the latter half of April abundance at these two stations had increased about thirty-fold. Lower levels of zoeal abundance (100 zoeae per station) occurred throughout the remainder of the bay.

During the first half of May, zoeal abundance was generally high throughout the outer bay but still low in the inner bay. Zoeal abundance at station 17 was very high, having increased from 208 zoeae during the latter half of April to nearly 5,000 zoeae during the first half of May. Zoeal abundance shifted slightly toward the inner bay during the second half of May, being highest at station 13. Abundance had dropped considerably along the outer sample transect.

Zoeal abundance during the first half of June was essentially identical to the previous sampling period except for a band of high abundance extending from the center of Kachemak Bay toward the southern entrance of the bay. During the latter half of June, zoeal abundance was markedly higher off Bluff Point toward Anchor Point and low elsewhere in the bay.

The above pattern of zoeal distribution is markedly similar to that of king crab zoeae during the same sampling period. Pandalid zoeae apparently were released primarily in outer Kachemak Bay in the vicinity of station 17. The zoeae were carried toward the inner bay only slightly before some of the zoeae were carried toward the southern entrance of the bay. Abundance of zoeae remained consistently higher in about the center of the bay throughout the sampling period. Apparently an influx of zoeae occurred during the latter half of June along the northern entrance to the bay. The inner bay is not likely a major rearing area for Pandalid zoeae.

SECTION III

SENSITIVITIES OF KACHEMAK BAY TO MAN'S IMPACTS

SECTION III

SENSITIVITIES OF KACHEMAK BAY TO MAN'S IMPACTS

As previously mentioned, Kachemak Bay is not the kind of "pristine" environment readily found within a few miles from its shore; the Kamishak side of Cook Inlet can be considered as having more of a "pristine" status than Kachemak Bay.

Kachemak Bay has and still is being subjected to an ever increasing spectrum of human encroachment: increasing population, increasing sewage discharge, increasing small boat traffic, increasing ocean going traffic, increasing use of its sheltered waters as emergency harbor of refuge to repair and salvage various types of damaged vessels and floating structures, increasing recreational pressures upon wildlife and fishes, increasing logging activities.

Man's impacts upon Kachemak Bay can be viewed from two standpoints:

1. <u>Impacts Resulting From Harvest of Renewable Resources</u>

   The fishing harvest impacts primarily upon the adult, reproductive segment of the population. Fisheries management constantly strive to maintain a commercial level of "sustained yield" to be harvested with a minimum level of effort. However, recurrent removal of large number of crabs, shrimps, herrings, salmons, from a restricted coastal area is bound to have a substantial impact upon the ecosystem, a facet of human impact upon the Kachemak Bay resources hardly investigated. For example, there is strong suggestions that in the Bering Sea, large scale harvest of pollocks and other commercial species are significantly altering the species composition, reduced harvest species being replaced by competitors previously held in check by the species being fished. Indication also are that reduction of the number of harvest species significantly affect the food supply of fur seal and some marine birds. Thus the impact of perhaps removing even a small excess of mature adults, upon the overall ecology of Kachemak Bay should be carefully considered.

2. Impacts From Disruption of the Natural Geo-Bio-Physical - Chemical Processes

The harvest of specific species and the disruption of the spectrum of species diversity of Kachemak Bay does not per se impair the ability of the environment to perform its life sustaining functions. However, recurrent addition and/or constant release of seemingly small quantities of substances foreign to the natural system, at rates and concentrations in excess of the natural ability of environmental processes to cope with the influx, usually alter the ability of the system to sustain life.

A brief discussion on the meaning of the term "pollution" seems apropos at this time. The term pollution is widely used, but seldom defined. Webster's definition show that the word "pollution" is a derivation of the middle English word "pollucion" meaning "emission of semen at other time than in coition, defilement, uncleanliness." Webster's definition hardly conveys the intended meaning of the word, as currently used.

A definition of pollution is given as:

> "An undesirable change in the physical, chemical or biological characteristics of our air, land and water, that may or will harmfully affect human life or that any other desirable species, or industrial processes, living conditions, or cultural assets; or that may or will waste or deteriorate our raw material resources". ("Waste Management and Control", Committee on Pollution, Natural Academy of Sciences, Natural Research Council, Washington, D.C., 1966).

The definition is highly anthropocentric, but conveys some of the complexities of man induced impacts.

The State statutory definition of pollution reads as follows:

> (15) "pollution" means the contamination or altering of waters, land or subsurface land of the state in a manner which creates a nuisance or makes waters, land or subsurface land unclean, or noxious, or impure, or unfit so that they are actually or potentially harmful or detrimental or injurious to public health, safety or welfare, to domestic, commercial industrial, or recreational use, or to livestock, wild animals, bird, fish, or other aquatic life;

From an ecosystem viewpoint, it is essential to recognize two basic types of pollutants.

a. <u>Nondegradable Pollutants</u>

Materials and poisons, such as aluminum cans, mercurial salts, long chain phenolic chemicals, DDT and other compounds that either do not degrade or degrade only very slowly in the natural environment; in other words, substances for which there are no evolved natural "assimilative" processes that can keep up with the rate at which man injects them into the ecosystem. Such non degradable pollutants not only accumulate but are often "biologically magnified" as they translocate through the food chain.

Removal of such pollutants, once introduced into the biosphere is difficult and costly; the easiest control is to initially prevent their dumpings into the environment, or at least strictly control their rate of influx to avoid toxic build ups. An important factor is that such pollutants can be biologically harmful or even biocidals at concentrations which tax the ability to detect and measure them.

b. Degradable Pollutants

Pollutants, such as domestic sewage, that can readily be decomposed by natural processes or by engineered systems (treatment plants). Such pollutants include substances for which there exist natural "assimilative" processes. Problems arise when the input into the environment overcomes the "assimilative" capacity. In contrast to pollution by toxic, non degradable substances, pollution by degradable pollutants can be controlled by combinations of mechnical and biologcal processes.

Odum (1971) interestingly points out that there are limits to the total amount of organic matter than can be decomposed within a given area and that, to avoid exceeding the overall limits of the biosphere, something like 4 to 5 acres of biologically productive land-fresh water space per person (plus the ocean) must be preserved.

The concept of the two basic kinds of pollution, as it applies to Kachemak Bay, can be expressed in terms of pollutional effects upon system energetics, as illustrated in the schematic model of Fig. 47. The diagram shows that, as long as the rate of input is moderate, degradable substances provide energy (organic matter) or nutrients (phosphate, nitrates) and selectively increase the productivity of the system by providing an energy subsidy. At high input rate, a critical range is reached that is frequently characterized by severe biological fluctuations (e.g. algal blooms). At still higher rates of inputs, the system essentially becomes poisoned by the overwhelming influx of degradable substances. In contrast, the diagram shows that non-degradable, toxic materials, stress the biological systems from the beginning, increasingly epressing productivity as their amounts increase; however, the effects can be hard to detect at low or chronic levels of influx.

The pollutional status of Kachemak Bay, for the present, lies close to the ordinate. Of great importance however, to the long term ecological quality of the bay, is the rate of inputs of ubiquitious toxic material which can induce long term biological changes, changes difficult to detect above the natural spectrum of fluctuations.

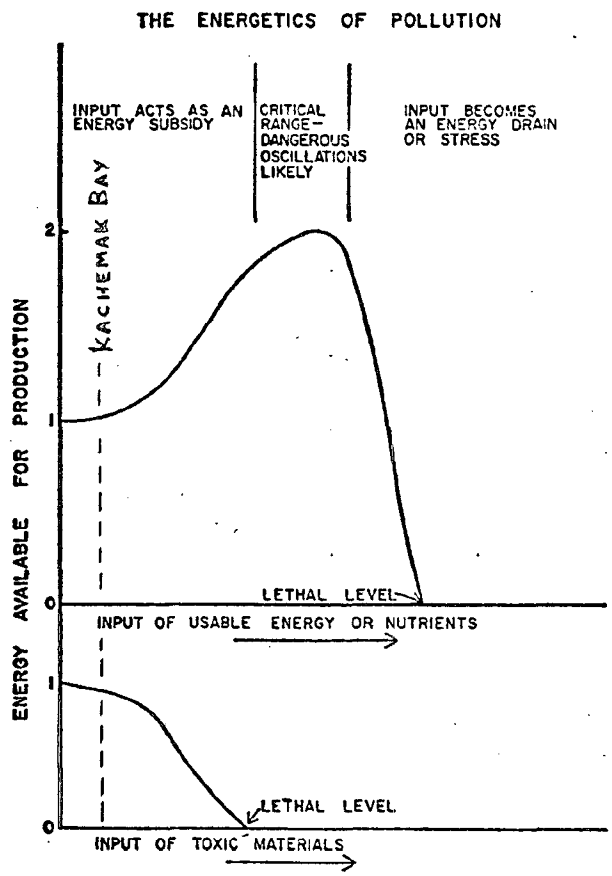
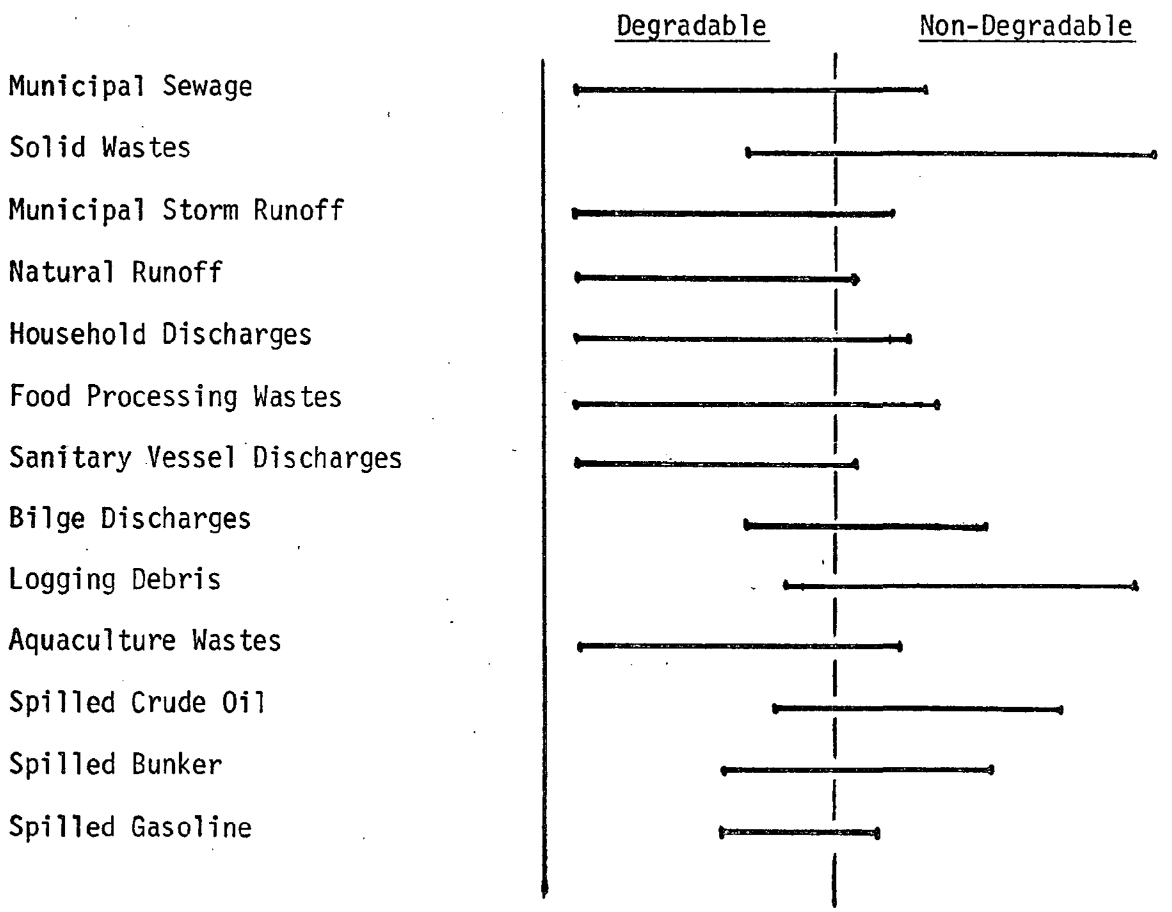


Fig. 47. Schematic Model of the Effects of the Two Types of Pollution. (from Odum, 1971)

Kachemak Bay is the recipient of a mix of discharges emanating from various forms of human activities. An identification of the type of wastes entering the Kachemak Bay marine environment can be schematized as follows:



POLLUTIONAL ASPECTS OF HYDROCARBONS INTRUSION INTO THE KACHEMAK BAY MARINE ENVIRONMENT

The basic issues of the Kachemak Bay fisheries - oil interests centers upon the public concerns on the impacts of oil upon the prime environment of the Bay.

Much of the concern relate to the hazards from oil spill, usually defined as a dramatic, large sudden release of either crude or refined oil by drilling or shipping activities. A moderate to large spill is a psychologically stirring event, highly visible and with readily observable dramatic effects upon all surface dwellers (marine birds, mammals), shoreline, beaches, pleasure crafts and beach dwellers. Not as psychologically stirring however are the constant, steady dripping and small spills of petroleum products in harbor, out of exhausts of outboard motors, or overboard pumping of bilges.

A large spill is a dramatic and usually locally catastrophic event, especially if it occurs in an area rich in birds, mammals and other marine life. If the spill occurs near population centers, public outcry and concern is great. Spills occurring in more remote areas, usually do not engender the same high levels of public clamour for protective action, as for example, in the recent grounding of the supertanker METULA in the Straits of Magellan.

Attempting to develop a predictive impact scenario for oil in Kachemak Bay can be somewhat speculative; however, a little publicized event, the spill resulting from the grounding of Royal Dutch Shell supertanker "METULA" in the Straits of Magellan on August 9, 1974, can serve as a documentable insight on the anatomy and aftermath of an oil spill in an environment very similar to the Kachemak Bay - Lower Cook Inlet environment. The following narrative by C.G. Gunnarson, summarizing preliminary on-site assessment of the impact of the spill underscores salient events:

The "Metula" Oil Spill

(C.G. Gunnarson - 1975)

(NOAA Marine Ecosystems Analysis Program Office)

Background

On 9 August 1974, the 206,000 ton supertanker "Metula", transiting the Strait of Magellan (Figure), at 14 1/2 knots ran aground. The ship stopped in a distance of 260 feet (80 meters), a small fraction of the two or three miles (3 to 5 km), ordinarily required to come to a halt. The METULA, owned by one subsidiary of Royal Dutch Shell, operated by a second, and leased to a third was carrying oil owned by the Chilean National Petroleum Authority (ENAP). The Government of Chile requested and received assistance from the U.S. Coast Guard who, in cooperation with the owner's salvage forces, transferred most of the oil to smaller tankers. The METULA floated free on 25 September 1974, after 51,500 tons of Saudi Arabian crude and 2,000 tons of Bunker-C had been spilled. The spill area is isolated (Figure48) and no cleanup procedures were attempted.

Physical Geography of the Strait of Magellan

Discovered in 1520 by Ferdinand Magellan, the Strait lies between Patagonia and Tierra del Fuego and since then, has served as an alternate shipping lane to the dangerous and longer route around Cape Horn through Drake Passage.

The southern Andean Cordillera, composed of granitic, volcanic, metamorphic, and sedimentary rocks lies along the Pacific Coast. Along the Atlantic, the area is one of glacial moraine with low hills and periglacial sediments of sizes varying from coarse sand to boulders along the shoreline and extensive loess deposits back from the coast. The ground surface often has strong parallel ridges, with some elongate salt pans, lined up with the prevailing westerly to northwesterly winds.

Mean air temperature near the Atlantic is 6.7°C (46°F) varying from 2.5°C (36°F) in July to 11.7°C (53°F) in January. Annual rainfall is about 300mm (12 in) along the Atlantic Coast to over 1500mm (60 in) in the higher cordillera. Winds are almost always westerly to northwesterly and commonly exceed 40 knots (75 km/h). Storm winds exceed 100 knots (185 km/h). During the spill, 70 knot (110 km/h) winds frequestly occured and once exceeded 115 knots (200 km/h).

Water currents in the spill area are mostly due to tides with average ranges of 7.6m (25 ft) at the eastern entrance to about 0.8m (2.5 ft) near Punta Arenas. Maximum currents occur in the narrows where the cross sectional area of the water is reduced (see Figure). Currents calculated from tide table data during the spill period are as much as 4.4 to 4.8m/sec (9.3 knots) in the First Narrows, depending on the tidal range. 9 knot (16 kn/h) currents have been measured in the

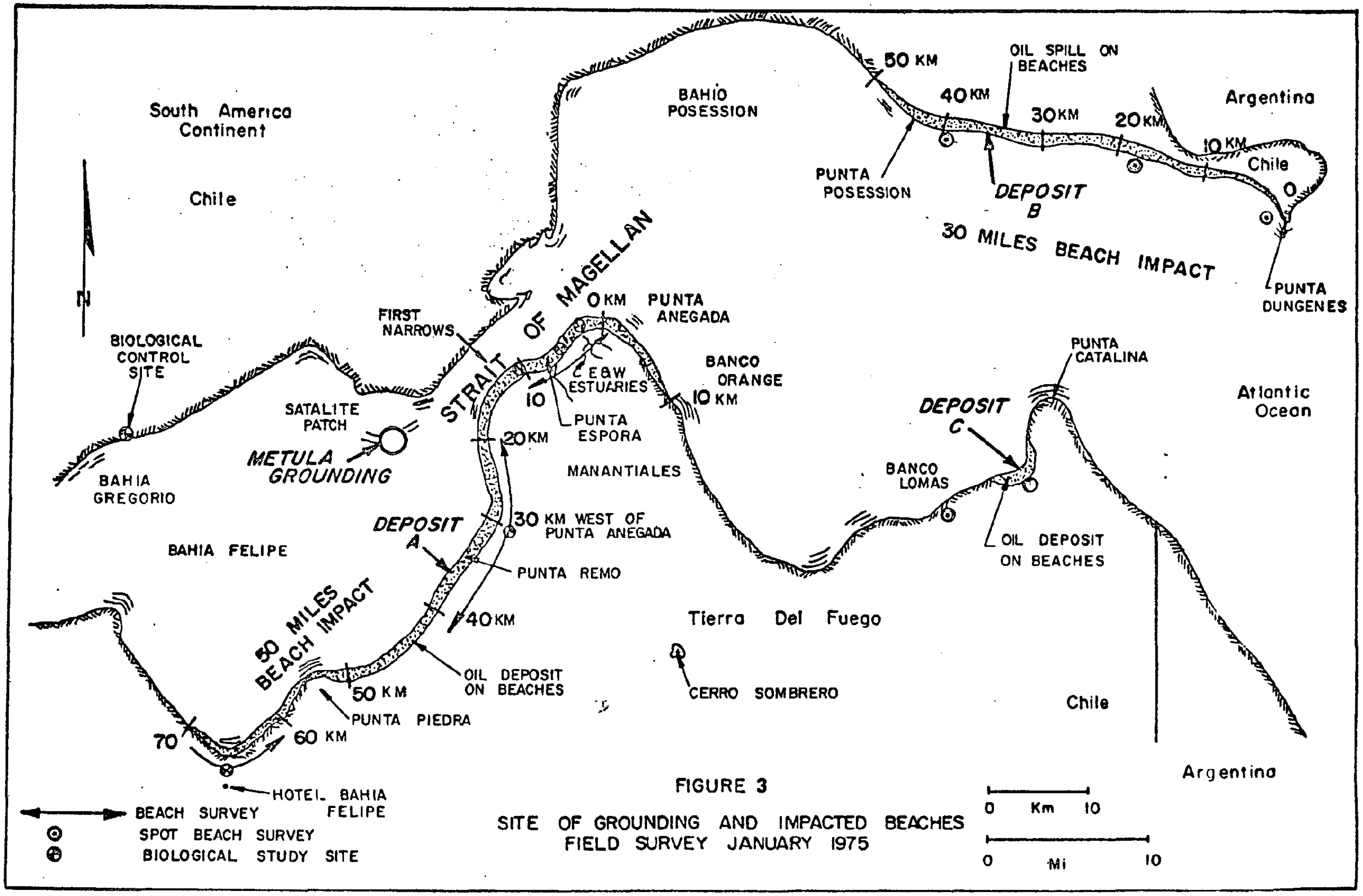


FIGURE 3

SITE OF GROUNDING AND IMPACTED BEACHES
FIELD SURVEY JANUARY 1975

Fig. 48. METULA Oil Spill. Straits of Magellan. 9 August 1975. (Gunnerson, 1975)

narrows by ENAP. In Bahia Filipe, where the oil was spilled and most of it went ashore, calculated maximum tidal currents are about 4 to 6 knots. Actual currents in the bays are affected by the wind as well as the tide.

Environmental Impacts of the Spill

Effects of the METULA spill are continuing. Some of these are still in the future. For instance, as lighter, more volatile fractions of the oil evaporate, an asphaltic surface will develop through which plants will be unable to force their way. Future research will be needed to determine the total impacts of the spill. Meanwhile, it is of interest to summarize observations made at the time of the spill in August 1974 and five months later in January 1975.

August 1974 Observations. Most of the environmental damage occurred during the spill, which began with an 6,000 ton initial loss of Saudi Aragian crude. A preliminary environmental assessment was made by Dr. Roy W. Hann, consultant to the Coast Guard. Up to 40,000 tons of oil were deposited along some 50 miles (80 km) of shoreline and in estuaries, mostly on Tierra del Fuego. Loadings in the more heavily oiled areas are estimated at from 5,000 to 10,000 tons per mile (3,000 to 6,000 tons per kilometer) of shoreline.

Amounts of oil deposited on beach varied widely according to rates of released, tides, and winds. Aerial observations showed the oil mostly along the Tierra del Fuego shore and, on August 20, spread over 1,000 square miles (2,500 km) of the eastern part of the Strait. No attempt was made at the time to evaluate satellite imagery of the spill.

Bird losses were originally estimated at from 600 to 2,000, mostly cormorants but including penguins, petrels, gulls, and others. Mussels, limpets, and starfish were also affected. Up to $10,000,000 was available from TOVALOP, established by the international oil companies and carriers, for oil spill cleanup and damage correction. This was not accepted by Chilean authorities although concern over possible damage to king crab fishery and other local marine resources was high.

Factors leading to this decision were: (1) effects were mostly limited to Tierra del Fuego where the main activities are sheep ranching and oil production; (2) the cleanup procedures were considered likely to cause even more damage than the spill; and (3) both local and long distance logistic support were, and still are, considered out of proportion to the possible benefits of remedial measures. Other considerations included uncertainty as to shared liability and litigation.

January 1975 Conditions. A second reconnaissance survey of the spill site was carried out in January 1975 by Dr. Hann, Dr. Dale Straughan, marine biologist from the University of Southern California and consultant to NOAA, Mr. H. Kenneth Adams, marine biologist from the U.S. Environmental Protection Agency, and the writer.

METULA oil was found where it was originally deposited, although there had been optimistic speculation that most of the oil had been driven by winds and surface currents into the Atlantic Ocean. The amount of oil deposited or remaining on the beaches and estuaries is not precisely known. Dr. Hann estimated that some 20,000 tons were present in January. However, the widespread extent and persistence of the oil is obvious, and to argue that most of the oil went to sea is to argue that the large-scale pollution which we saw was due to a smaller quantity of oil.

In the most heavily oiled areas on the southern shore of Bahia Filipe and the First Narrows, and in a large salt marsh, oil is ubiquitous. Heavily oiled cobbles are found on some beach areas. Oil and mousse (en emulsion with from 5% to 20% water and with the appearance of chocolate mousse) which was originally deposited on the beach is flowing through saturated beach sediments to mean tide level. In some areas, this oil colors the breakers and is returned to the beach as swash marks. Seasonal and diurnal heating of the dark-colored oil deposits promotes bleeding and flowing of the oil on the surface and subsurface flow of the oil through the sediments.

Biological impacts of the oil spill were and still are severe. Local mussel and fin-fisheries were reported by one of the fishermen to have been moved to other areas because of taste problems. In the salt marsh, large quantities of oil were found floating on the surface of tidal channels, deposited on tidal flats, and in isolated patches where they had apparently been blown by the wind. There are large blackened areas which once were covered with green marsh plants.

Oiled birds were found landward of shore areas in which the original counts of dead birds were made. In one area, 22 dead cormorants were found within a 25 yard (25 meter) radius which had not previously been counted. Samples of intertidal organisms and sediments were collected by Dr. Straughan at a total 30 quadrats located in areas of heavy, light, or no visible oil contamination. A total of 40 sediment and 7 tissue (mussel) samples were collected for quantitative petroleum hydrocarbon analyses.

The "Metula" mishaps spilled about 51,500 tons of Saudi-Arabia crude or about 20 million gallons which spread a little over 1000 square miles of the coast and marine waters of the strait. (Fig. 48)

Supertankers do not ploy the waters of Cook Inlet yet, the biggest tanker transiting through the inlet being in the 70,000 tons range. It must be noted that a mishap by a 70,000 ton tanker, with a capacity of about 500,000 barrels, in Lower Cook Inlet could result in a spill similar in magnitude to the one of the "Metula". Thus the "Metula" mishap, in an area, environmentally very similar to Lower Cook Inlet, can serve for a basis to examine the consequences of an oil spill in the Lower Cook Inlet - Kachemak area. It should also be noted, that the magnitude of the "Metula" spill can also be likened to part of the amount that could emanate from an uncontrolled oil well in the Inlet.

Anatomy and Potential Impacts of an Oil Spill Upon Kachemak Bay

Attempting to fully quantify both the short and long term impacts of an oil spilled in to Kachemak Bay, even if all the intricacies of the geo-bio/physical chemical processes were known, would be unrealistic due to the large of initial variables to be considered such as; volume of the spill, chemical composition of the oil, location of the origin of the spill, local and regional variabilities in currents, wind, sea state, sea surface roughness, sea water and air temperatures, local and regional variabilities in the concentration and types of inorganic and organic particulate, strength of the vertical density stratification, occurrence of sea ice and shore ice, amount of daylight and intensity of sunlight, (Fig. 49).

It must be underscored at this time that in general, the post mortem investigation of an oil spill are usually of short duration. This point was stressed in the April 1974 CEQ, Oil and Gas Environmental Assessment (p. 40) which stated:

> "Many observations depend more on the lenth of the study than on the actual time the oil remains in the habitat". Hence these observations relate to) minimum residence time of oil.
> In many cases, the investigative reports terminated their data collection before the oil was no longer detectable (either visually and analytically)."

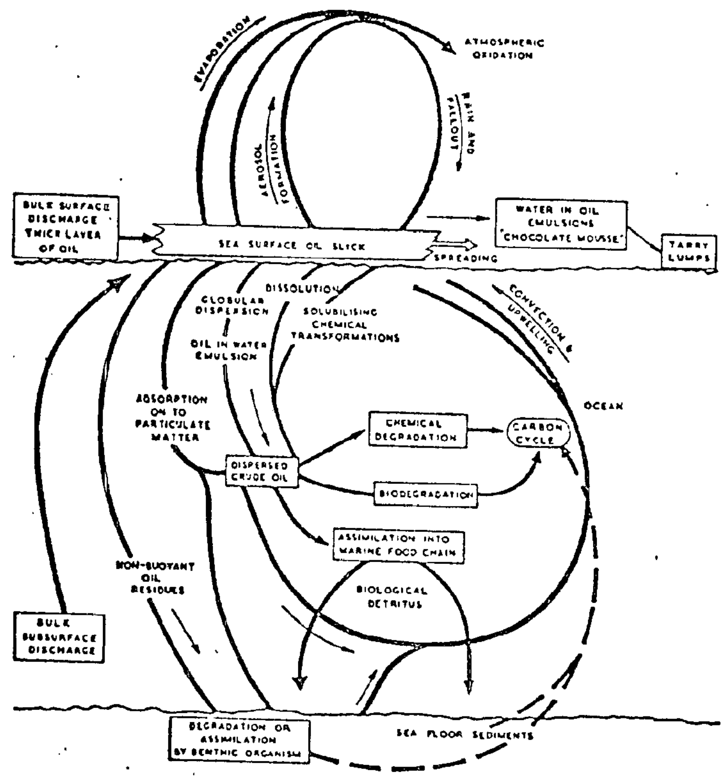


Fig. 49 - Processes controlling the fate of spilled crude oil in the ocean. (Burwood and Speers - 1974)

At present, only few investigators study the long term fate of spilled oil (e.g. Blumer et al on the West Falmouth Oil Spill). Thus any attempts to adapt existing results to project the extent and levels of impacts of oil spilled upon the Kachemak Bay marine environment must be tempered with the realization that the reported results usually refer to minimum effects, usually of the more acute levels of persistance and effects.

As pointed out in an article by K.G. Hay (1974), results from a wide spectrum of multidisplinary investigative activities can affirm certain facts and put to rest certain speculations about the fate and effects of oil upon the marine system.

A. - Behavior and Fate of Spilled Oil.

The anatomy of an oil spill in Kachemak Bay shall be discussed within the framework of the fates and effects format of the NAS Publication "Petroleum in the Marine Environment" (1975).

1. Oil Dosage

Spills occurring in small confined areas, so that the oil can be contained for long periods of time, will cause greater damage than spills released in the relatively open sea.

The environment of Kachemak Bay provides for nearly all ranges of openness or containment of spilled oil. Its southern shore characteristics by many embayments, can, especially during the periods of the year of little or no runoff, usually also associated with shore line conditions, has all the potential for high periods of retention for any spilled material, even for relatively small spills. Local wind factors with sheltering and/or channelling effects of the steep topography extent a primary control upon the rentention or dispensal of a spill.

The inner portion of Kachemak Bay, especially the area most utilized by large vessels, the degree of initial oil release will obviously be the controlling factor as to the extent to which the area will be affected.

Estimate of the expected surface area to be covered by a given amount of oil are difficult to make, as a number of factors modify the composition and the spreading behavior of the oil.

The amount of oil that could be spilled into the inner portion of Kachemak Bay can range from a few gallons to in excess of perhaps in excess of 10 million gallons (about 45,000 bls) from a tanker.

Of interest, referring to the METULA incident, is the high dosage of oil on various beaches (5 to 10,000 tons/mile). The surface area of the inner Bay, eastward of Homer Spit, is about 96 square nautical Miles. Assuming an even distribution of oil over the entire inner bay, about 400 bls of oil could be expected per square mile.

Large spillage in the outer bay, would obviously have different dosage depending upon the points of relase. The dosage from an uncontrolled well, drilled at the proposed exploratory well locations in outer Kachemak Bay are unquantifiable at this time, due to the absence of information about the size and volume of flow.

2. Dispersal of Oil

The fate and biological effects of oil, once relased in marine waters such as those of Kachemak Bay, is controlled by the initial physio-chemical characteristics of the oil. Crude and refined products exhibit a wide complexity and variations in their physical-chemical composition. Since the physical-chemical processess the oil will undergo once introduced into the marine environment depends upon its composition, a knowledge of the composition and physical-chemical properties of the spilled material is an essential pre-requisite to predicting its fate.

The most likely types of oil that can be spilled in Kachemak Bay consist of crude oil, both local and imported from the Middle East, Bunker C or No. 6 fuel oil, diesel or No. 2 fuel oil and light petroleum products such as kerosene and gasoline.

The composition of "average" crude can be most easily described in terms of its:

Molecular Size		Molecular Type	
Gasoline	30%	Paraffine (alkanes)	30%
Kerosene	10%	Naphtene Hydrocarbons	50%
Light Distillate	15%	Aromatic Hydrocarbons	15%
Heavy Distillate	25%	Nitrogen, sulfur, oxygen containing compounds	5%
Residues	20%		

Moore et al (1973) distinguished light fractions of oil, as summarized in table.

The dispersal of oil includes: spreading, evaporation, air-sea interchange, emulsification, solution, sinking, chemical oxidation, microbial oxidation, photo-chemical reactions and beaching.

TABLE 22

BASIC DATA FOR OIL COMPOSITION MODEL

(from Moore et al., 1973)

Fraction	Description[a]	% by wt.[a] in Crude Oil	Density[b] (gm/ml)	Boiling Point[b] (°C)	Molecular Weight[b]	Vapor Press.[b] @ 20°C (mm)	Solubility[c] (gm/10^6 gm Distilled H_2O)
1	Paraffin C_6-C_{12}	.1-20	.66-.77	69-230	86-170	110-.1	9.5-.01
2	Paraffin C_{13}-C_{25}	0^+-10	.77-.78	230-405	184-352	.1	.01-.004
3	Cycloparaffin C_6-C_{12}	5-30	.75-.9	70-230	84-164	100-1.	55-1.
4	Cycloparaffin C_{13}-C_{23}	5-30	.9-1.	230-405	156-318	1.-0	1.-0
5	Aromatic (Mono- and di-Cyclic) C_6-C_{11}	0-5	.88-1.1	80-240	78-143	72-.1	1780.-0.
6	Aromatic (Poly-Cyclic) C_{12}-C_{18}	0^+-5	1.1-1.2	240-400	128-234	.1-0	12.5-0
7	Naphtheno-Aromatic C_9-C_{25}	5-30	.97-1.2	180-400	116-300	1.-0	1.-0
8	Residual (including heter-ocycles)	10-70	1.-1.1	>400	300-900	0	0

22

a. Spreading

Spreading occurs rapidly at first; Fay (1969) investigating the spread of oil on a calm sea, concluded that gravitational effects (hydraulic head) controlled the initial spreading of the oil. As the oil thins however, interfacial tension between oil and water becomes influential. From available spill data, it is observed that even viscous crudes spread into thin layers that become influenced by surface effects. For example, Berridge et al (1968) calculates that 100 cu. m. of various crudes will thin to an average value of . 55 cm within 17 minutes, .12 cm after 3 hours and .003 cm after 28 hours.

Once a spill has thinned to the point that surface forces play an important role, the oil layer is no longer continuous, but becomes fragmented by wind and waves into patches and wind rows where thicker layers of oil are in equilibrium with thinner films

rich in surface active compounds. Observations on experimental spills (Jeffrey, 1973; Hollinger and Mennella, 1973) indicate that patches of oil several millimeters thick were surrounded by thin films of less than 4 mm - approximately 90% of the volume of the oil was in the thicker layers that occupied only 10% of the visible slick area (figure 50).

Wind, waves and eddies determine the shape and direction of the spill. Blokker (1964) considered the wind as being the most influential factor, the oil drifting at about 3-5% of the wind speed.

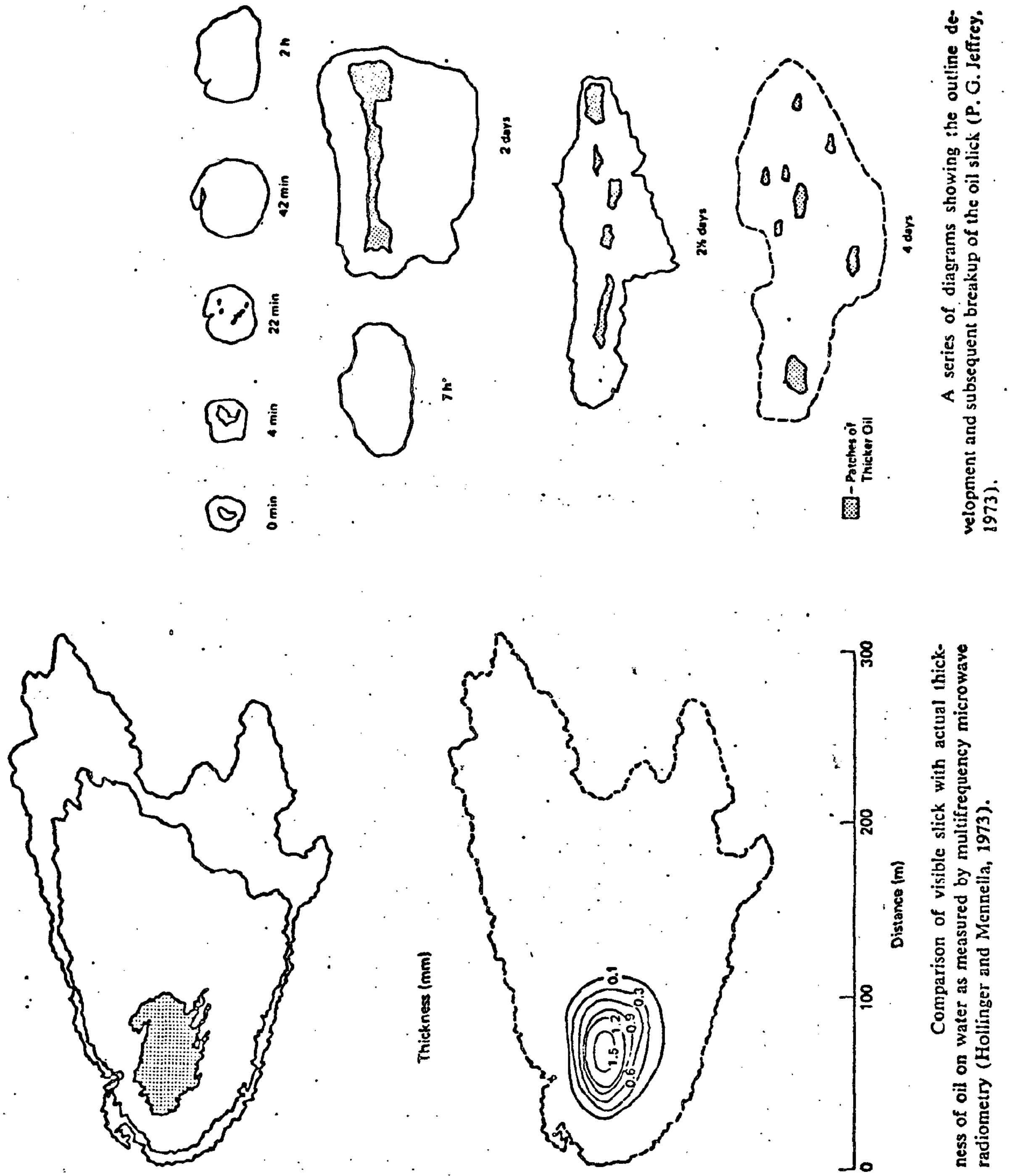
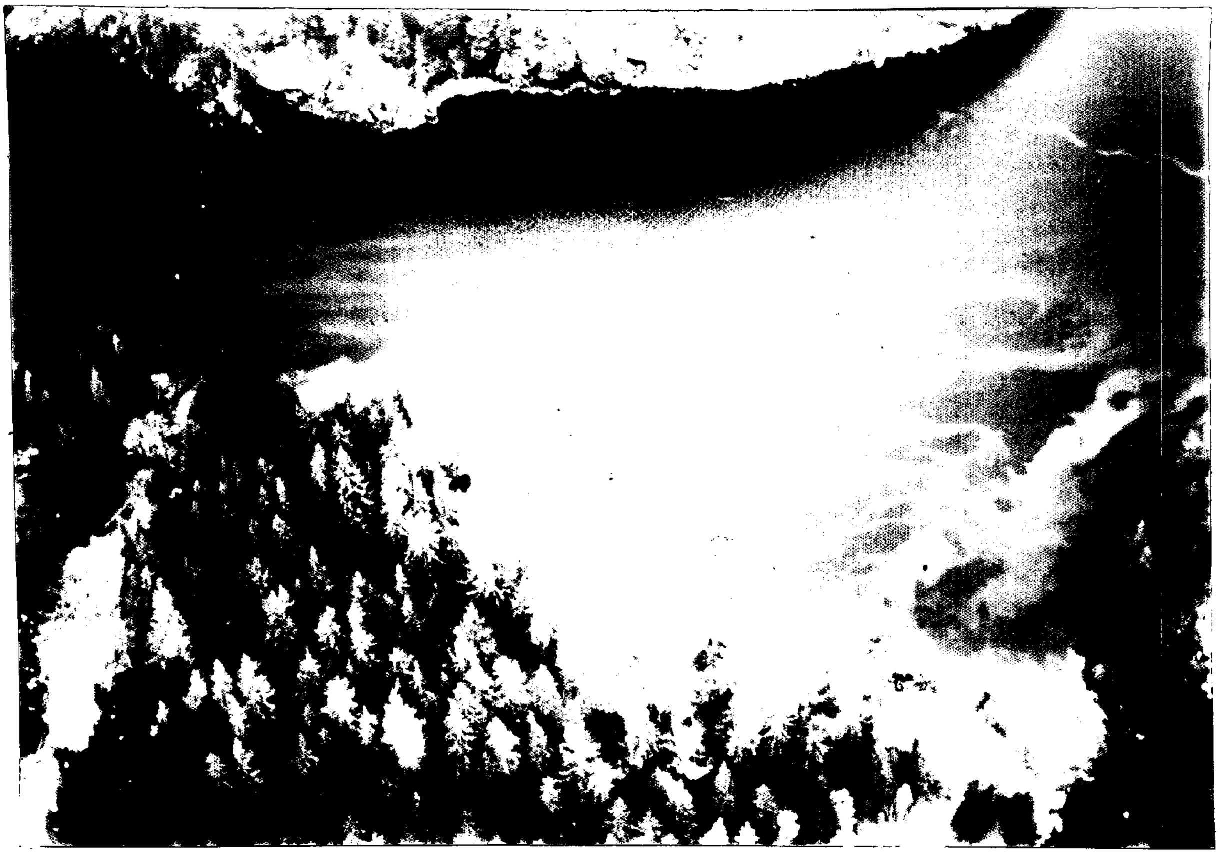


Fig. 50. Spreading of an Oil Slick.



Small oil spill - Halibut Cove (unreported)

The importance of the surface active constituents in spreading and dispersion of oil in water is demonstrated by the fact that most pure hydrocarbons do no spread spontaneously by surface forces. Surface active constituents are known to exist in crude oil. Dunning et al (1953, 1954, 1956) attributed the major interfacial activities from Oklahoma and California crudes to vanadium and nickel porphyrin complexes. Canaveri (1970) identifies prophyrin emulsifier from Kuwait crude. Nitrogen-sulfur-oxygen compounds (NSO) have also been shown (Seifert and Howells, 1969) to be highly surface active. Such compounds enhance the weathering processes by increasing the surface to volume ratio, giving a greater exposure to the air and underlying water. The cessation of slick growth has been attributed by Fay (1971) to the decrease in spreading tendency from loss of NSO compounds by dissolution or by inclusion into tar bases.

The spreading of an oil slick in Kachemak Bay will be greatly influenced by the regime of the circulation. The results of the transport measurements performed to date clearly show that the pattern of transport of the spill will be complex and will depend to a great extent to the stage of the tide at the onset of the spill to the location within the bay, and to the effects of the local winds.

The present data indicate that:

1.) Hydrocarbons released near the inner portion of the spit would most likely spread along the seaward face of the spit and along the shores between the spit and Bluff Point.

2.) Hydrocarbons released in the vicinity of the Shell-SoCal drilling site would most likely affect the shore between Anchor and Bluff Point, an area where a number of otters have been obvserved in the kelp beds, along the shore.

3.) Hydrocarbons released in the vicinity of Point Pogibshi would follow several paths, depending upon the prevailing tidal regime. They spread along the southern shore and enter various embayments travel to the Anchor Point-Homer Spit shore, travel up channel or even reach the Kamishak side of the inlet.

4.) Hydrocarbons released within the inner portion of the outer bay would follow a circuitous route, within the gyres system.

Of interest is the predicted oil spill trajectory inferred by Miller and Britch (1975) for a location in outer Kachemak Bay. The prediction shows inferred trajectories for various wind speeds and directions, neglecting the effects of the tidal circulation, and an inferred trajectory with the combined effects of winds and tides (Fig. 51).

Analysis of present information on the processes controlling the spreading of spilled oil indicate that significant knowledge has been acquired on some of the controlling factors. However, the degree of knowledge so far acquired can only provide gross understanding of spill spreading processes. At this time, one can only reflect upon the statement of p. 1, chapter I. of the MIT studies on "Oil Spill Trajectory Studies for the Atlantic

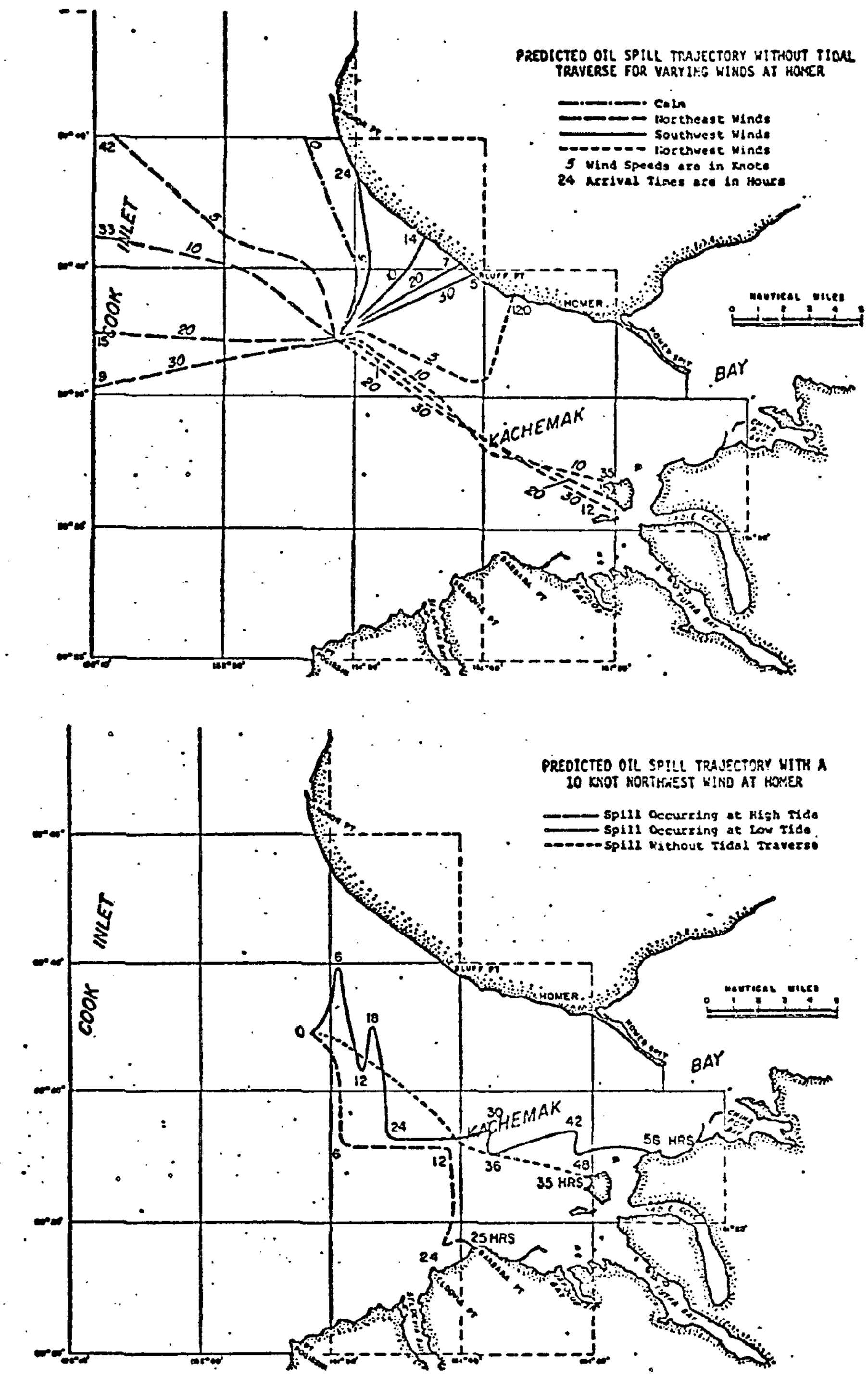


Fig. 51. Inferred Oil Spill Trajectories for Kachemak Bay. (Miller and Britch, 1975)

Coast and Gulf of Alaska" (CBQ Report - OCS Oil and Gas, An Environmental Assessment - April 1974).

> "Despite the ten or fifteen papers available on the subject of oil spill transport in the ocean, it is fairly clear that we do not understand how the waves passing underneath an oil slick, the wind blowing over an oil slick, and the gross motions of the underlying water combine to move the oil. In fact, we find that the motions of the waters lying right at the air-sea interface, in the absence of oil are still the subject of much current research."

Much work has been done, and much understanding acquired, but for Kachemak Bay, a spreading spill will require real time, constant field monitoring for control and clean up.

b. Sea-Air Transfer Processes

Hydrocarbons fractions, spilled upon the surface of Kachemak Bay will be transferred to the atmosphere by evaporation and by wave produced spray and bursting bubbles.

The rate at which spilled oil evaporates off the sea is determined by its chemical composition. The more volatile components, gasoline and kerosene, can, according to Kreider (1971) be volatized within 10 days. Light distillates show limited volatility and will be retained for the most part in the slick. Heavy distillates and residues do not volatize readily. Evaporation alone can remove 50% of the hydrocarbons from an "average" spilled crude, depleting the lower boiling components (fractions 1, 3, and 5 shown on table).

The evaporated hydrocarbons enter the atmospheric pool of hydrocarbons. Chemical reactions in the atmosphere convert an unknown amount of these hydrocarbons into less volatile non-hydrocarbon compounds. The fates and effects of such compounds are unknown.

Hydrocarbons are also removed by wave produced spray and bursting bubbles. Rough seas tend to favor losses of hydrocarbons to the atmosphere as spray and bursting bubbles eject both volatile and non volatile components. However, wave action and turbulence also favors emulsification of the oil and facilitate its solution.

Examination of the drogue data and of the inferred spill trajectories of Miller and Britch, indicate that, due to the rather restricted size of Kachemak Bay, oil would reach the shores within a few hours to less than 4 days. Based upon present estimates for evaporation of the light oil fractions, most of the oil reaching the shores would still contain a high percentage of its volatile fractions. At this time no estimate can be made of the magnitude of the fraction of oil ejected to the atmosphere by spray and bursting bubble that would settle upon the coastal area bordering the bay. The METULA incident showed that spray will induce heavy coatings of the back shores by oil. Under appropriate sets of wind and wave conditions, sea-air transfer processes can be a major factor in translocating spilled oil beyond the shorelines.

c. Emulsification

Turbulence and sea surface agitation will induce two types of emulsion: oil-in-water and water-in-oil.

The oil-in-water emulsions consist of droplets of oil, up to a few mm in diameter which are stabilized by the presence of various hydrophylic groups naturally present in crude oil but usually removed during refining. (Pilpel, 1968). Oil-in-water emulsions are readily miscible in sea water and are easily dispersed by currents and turbulence. Forester (1971) investigated these fine particles in details following the spill at Chedabucto Bay, Nova Scotia. He observed particles ranging from 5 mm to several mm dispersing as a result of wave agitation down to a depth of 80 m inside the Bay and down to 45 m, 65 km outside the bay; near surface distribution of particles extended 250 km SW along the Nova Scotia coast. The spill released approximately 108,000 bbls of Bunker C fuel oil into the bay, in Feburary 1970.

Water-in-oil emulsions are formed particularly by heavy asphaltic crudes and residual oils. Water-in-oil emulsions are not miscilble with sea water, consisting of droplets of water enclosed into sheaths of oil rendered stable by the presence of various resinous and asphaltic materials naturally occurring in crudes. These emulsions can contain up to 80% water and have a consistency ranging from thick cream to road tar. They tend to occur as somewhat coherent semi-solid lumps often referred to as "chocolate mousse". Studies by Dodd (1971) show that the rate of formulation of water-in-oil emulsions under comparable conditions vary dramatically with the nature of the oil.

The water-in-oil emulsions usually remain as thick, greasy layers or may break up into lumps. Some washes ashore, some sinks to the bottom and the rest gradually decomposes. Three factors induce an oil-in-water emulsion to increase its specific gravity and sink. (ZoBell, 1964): Adsorbption of sand, clay, silt, and skeletal remains of various organisms, spontaneous oxidation and microbial oxidation.

Sinking occurs most rapidly in shallow water and in the intertidal zone, where the concentrations of suspended solid is high. Along beaches and muddy estuaries, the oil material is soon located with sand, small pebbles, shells and other debris and turns into a hard mass. Along muddy and sandy beaches, a good deal of it becomes buried in the intertidal zone.

Kinney (1970) observed that, in upper Cook Inlet, crude oil changes rapidly from its initial state of black oil spreading along the surface into particles of water-in-oil emulsion, exhibiting considerable variations in size and a high degree of stability. Cook Inlet silt was observed to have no apparent effects upon emulsion formulation or sinking of Cook Inlet Crude (Button et al 1970), a fact consistent with what is known about the displacement of hydrogen bonded water from clay surfaces by non-polar particles. Initial emulsification from an experimental spill of 20 gallons of Cook Inlet Crude was very rapid. Within three hours the predominant character of the spill was black patches of emulsion, ranking in size from very small to up to two inches in size, some exhibiting almost fibrous appearance, interspaced in a light surface slick. Winds averaged about 10 knots (Kinney, 1970).

d. Solution

Present information indicates that water-soluble aromatics and aliphatic hydrocarbons exhibit sublethal effects on marine organisms at concentrations of 10-100 ppb, lethal toxicity at 0.1-10 ppm for most larval stages and lethal effects at 1-100 ppm for most adult organisms (Moore et al, 1973). Although little is known of the relative percentages of loss of such components by evaporation and solution, it is usually assumed that most is lost mainly by evaporation. Detailed understanding of the fate of such components, especially during the early stages of slick aging is crucial, as the low boiling hydrocarbon fractions contain almost all of the lethal components of the slick (Blumer, 1971); investigations on the "weathering" of crude oil slicks on the sea have demonstrated that all of the lower boiling components evaporate or dissolve within a few hours of slick initiation (James et al, 1973; Sivadier and Mikolaj, 1973).

Water solubility of hydrocarbons drops drastically as the carbon number increases (McAuliffe, 1969; Baker, 1967). Solution preferentially removes the lower molecular weight components; however, aromatic hydrocarbons have a higher solubility than n-paraffin at the same boiling point (Blumer, 1970).

Dissolution of hydrocarbon fractions into sea water can also take place over a period of time, after all visible evidences of the slick have disappeared. McIlvaine (1974) indicates that dissolved oil was observed during oil spill survey during finger printing analysis of waters taken from control stations showing no evidence of surface slicks or iridescence. Blumer and Sass (1972), working with No. 2 fuel oil showed that low boiling aromatics (C-1 to C-3) incorporated in the sediments were being replaced by highly soluble aromatics, suggesting that the low carbon aromatics were going into solution rather than being degraded by the marine microfiora. McIlvaine indicates that there is direct evidence that refined hydrocarbons can go into solution and that such solution is mainly restricted to the toxic aromatic fractions.

The emulsification and solution processes controlling the fate of spilled hydrocarbons are of great importance to the assessment of spill impacts upon the Kachemak Bay environment. As previously commented, the relatively small geographical extent of the Bay, the rather high residence time of the spilled material within the semi-daily tidal eddies and the semi-permanent gyre, indicates that the basic circulation and transport process would favor significant incorporation of spilled material within the water column, beach, intertidal and subtidal sediments.

The processes of incorporation and the environmental fate of the spilled material will be governed by the initial composition of the spilled hydrocarbons. Fuel oil would probably be incorporated as an oil-in-water emulsion and, under various conditions of sea surface roughness, could be incorporated throughout much of the water column of the Bay. Its potential toxicity to marine life would be high.

Crude oil would take to rapidly form water-in-oil emulsions, giving rise to thick tarry lumps with formation of some "chocolate mousses", and much of the material would either coat the shore with a viscous layer or sink to the bottom. The fate of the material once sunk beneath the surface is difficult to ascertain. During the San Francisco spill, the writer (Dr. M.P. Wennekens) obtained reports from divers working in Bolinas Bay, at the entrance to San Francisco Bay, stating that a two to three foot layer of viscous oily globules, some of them several inches long, could be found suspended above the bottom, the globules being in hydrostatic equilibrium within the near bottom turbid layer often observed along the coast. Part of the sunken oil would periodically wash ashore, necessitating several recleaning of beaches.

The subsurface fate of emulsified and dissolved constituents will be greatly influenced and controlled by the vertical density stratification. As shown in the beginning of the report, the Bay is characterized by a complex, seasonal regime of density stratification. Work by LaFond (1969) and others has demonstrated the close relationships between subsurfaced distribution of sharp density layers and the concentration of particulates (and planktons). The subsurface density stratification behave in a fashion similar to an atmospheric inversion layer in the entrapment of particulates. The seasonal density stratification of Kachemak Bay will be a significant factor in the control of dispersal of emulsified and dissolved hydrocarbons.

e. Sedimentation

The NAS report (Petroleum in the Marine Environment, 1975) notes that: "Actual sedimentation plays an essential part in the fate of oil in the marine environment, however, virtually no systematic field work has been done on this subject and it is difficult to make more than a qualitative prediction about either the rates of sedimentation or the amounts of petroleum to be found in the sediments".

Decomposition of petroleum components in the marine environment of Kachemak Bay must consider deposition on the shore, intertidal and subtidal areas. Processes increasing the density of the spilled oil include evaporation, solution, flocculation and agglutination of oily particles, adsorption to particulates, absorption into particulates.

Following a spill, considerable incorporation of oil into the sediments can occur within a few weeks (Kolpack, 1971). As previously noted, evaporation and solution, combined with other reaction such as oxidation, contribute to the formation of semi-solid globules. As the more volatile constituents of the oil are preferrentially removed, the specific gravity of the remaining fractions induces the remaining oil to become denser. Sea water has a specific gravity (density) of about

1.025; from table 22, it can be seen that the specific gravities of fractions 4 through 8 would readily make them sink to the bottom.

Agglutination of dispersed liquid oil particles have been observed following spill (Forrester, 1971) and formation of of oily aggregrates in Upper Cook Inlet was, as previously mentioned, commented upon by Kinney.

In the coastal-estuarine conditions of Kachemak Bay, usually characterized by a certain amount of turbidity, especially along the shoreline subjected to wave action, agglutination of particulates by oily residues can be expected to be high. Under such conditions entrainement of oil into bottom deposit is greatly enhanced, especially along the extensive tidal and shallow subtidal area characterized by fine grain sediments. Many Bunker-C oils and some heavy crudes have specific gravities near 1.0, thus only slight addition of particulate matter will induce their sinking.

Sorption processes induce clay minerals to adsorb large quantities of dissolved hydrocarbons (Meyers, 1972). Organic matter in the clay contribute to the process; sorbtion increases with salinity, but decreases with temperature. The rate of incorporation of oil into the sediments can also be acclerated by the fecal pelleting of particulate matter by organisms. The magnitude of the amount of fecal material that can be generated can be gauged by observations showing that oysters covering 1 acre of estuary would deposit about 7.6 metric tons (dry weight) of fecal pellets in 11 days, which would come to about 290 metric tons per year or the equivalent of about 46 kg/m^2 (1 acre = 4.1×10^3 M^2).

The movement of oil, once incorporated in the sediments, is poorly understood. Although the chemical composition of the oil does not appear to be altered materially, oil incorporated into the unconsolidated sediments may persist for long periods of time, especially the higher boiling fractions. Loss of low boiling fractions proceed at much lower rates (months as compared to hours or days) as suggested by Blumer and Sass (1972) observations on the W. Falmouth spill. Blumer et al (1971), Kolpack et al (1971) indicate that lateral spreading (up to 1 km) can continue for at least several months after a spill.

In the intertidal area, the fate of the oil will depend upon the type of substrate. In the Kachemak Bay area, several types of substrate are present: fine grained sediments of the tidal marshes, protected embayements and semi-exposed extensive intertidal flats, coarse sediments along the more open beaches subjected to wave action, rocky shores with extensive intertidal and subtidal algal matting.

On beaches, reworking of liquid and particulate oil takes place on the foreshore (Asthana and Marlow, 1970). On unprotected beaches, subjected to more energetic wave action, such as the beaches of the Bluff Point area, the entire amount of oily residues can be deposited during one tidal cycle and removed on the next one, the residues transgressing progressively longshorewards with the prevailing transport.

Tarry globules on beaches tend to accumulate large amounts of sediments, become rounded and finally behave like pebbles (Ludwig and Carter, 1961). They tend to concentrate near and above normal high tides, where the degradation of large masses become very slow (Blumer et al 1973).

In the extensive fine grained intertidal and shallow subtidal areas of the Bay, sedimentation processes are quite active, so that layer of oily material can be rather quickly buried. Much reworking of the sediments takes place by the action of the often prevalent wavelets stirring up the surface of the shallows. Once on the bottom and incorporated into the sediments, the oil constituents will be ingested by the various benthic forms and pelletized. Once within the sediments, further degradation will proceed under anaerobic conditions (Gebelin, 1971).

Along rocky shores, retention of the liquid and finely dispensed oil is usually controlled by the algal matting of the lower intertidal, upper subtidal region and pores of the rocky surface. Large amounts of petroleum can become entrapped in the holdfast-sediment complex of the algal mat and the oily residues then are progressively leached out by tidal action over long periods of time (Foster et al, 1971).

Again, making a parallel between the METULA incident and the potentials for a mishap in Kachemak Bay, one must note that reports from the METULA incident only referred to accumulation of oil on the beaches and intertidal area. It is interesting to note that the grounding occurred in August, at the peak of the Austral winter. It can be postulated at this time, from the fact that the spill consisted primarily of crude, that much of the oil formed a water-in-oil emulsion, which would greatly favor the formation of heavy oil globules and some "chocolate mousse". Thus much of the oil probably was initially subtidally deposited along the bottom within the general area of the spill. The January observations (mid Austral summer) still showed massive retention of oil in the salt marshes and in sediments and that oil leaked out was returned to the beach as swash layers. Thus the persistence of oil in marshy, intertidal and subtidal sediments can be high.

The persistence of oil in sediments is also documented by several series of observations undertaken to assess the long term fate of spilled oil (CEQ Report - OCS Oil and Gas - An Environmental Assessment, 1974).

Chedabucto Bay - Nova Scotia - Canada

108,000 bls (about 22,000 tons) of No. 6 Bunker C fuel oil was spilled into the bay on February 4, 1970. The oil entered two habitats: sandy beaches and rocky shores. U.V. spectrophotometry showed that 26 months after the spill (April 1972), about 300 mg of Bunker per gram (wet weight) of fine sediments remained in the first three feet (10 M.), an amount comparable to the concentration initially measured shortly after the spill. In contrast, measurements in gravelly sediments showed only traces of oil.

Re-oiling due to the original spill, reoccurred in the bay as late as the summer of 1973. About 50% of the original oil content was still present in the lagoons and salt marshes. Little residual oil was found on rocky shores.

West Falmouth - Massachusetts

An estimated 4,500 bls (about 1100 tons) of No. 2 fuel oil was spilled off West Falmouth Harbor on September 16, 1969.

In the heaviest hit area, two years after the spill, 117 mg of fuel oil/per 100 grams (dry weight) of sediment were still observed; from gas chromatography, it was demonstrated that 30% of the oil consisted of aromatics. Oil was found in the marshes at least five feet below the surface of the sediments and undegraded fuel oil was still present four years after the spill. Researchers at Woods Hole Oceanographic Institute estimate a persistence time in excess of five years for this relatively small spill.

Santa Barbara, California

Starting on January 28, 1969, and lasting for several weeks, a wild well spilled in excess of 33,000 bls (about 6600 tons) of oil. Sediment samples analyzed for oil in March, May and June of 1970 showed no reduction in oil content; oil has been measured in sediments as late as June 1970. Straughan (1973) comments that the effects of oil on rocky shores were least, and that exposed sandy beaches recovered from oil contamination during 1972-73.

The CEQ report indicates that the data from eight different

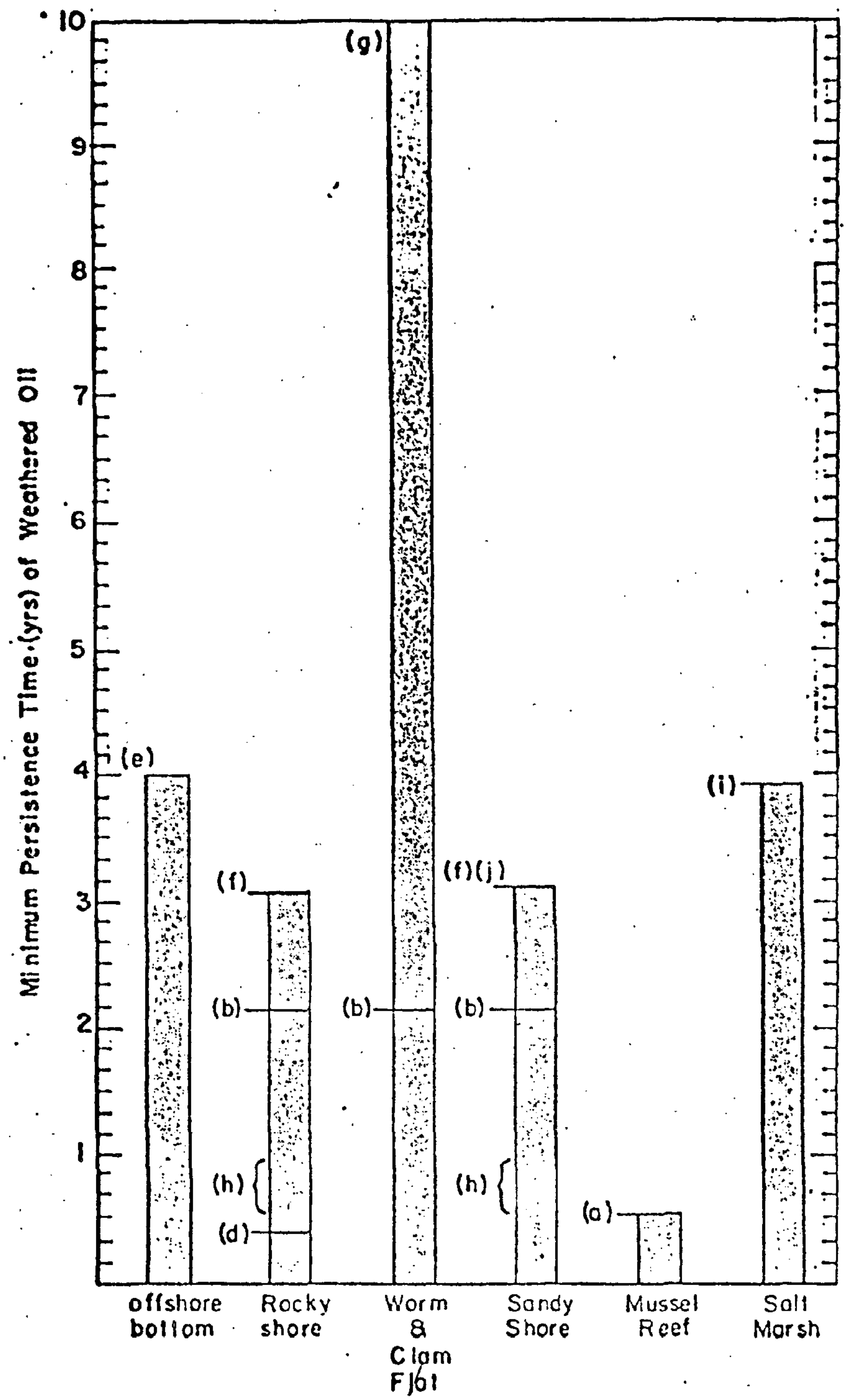


Fig. 52. Observed persistence of petroleum substances in various marine habitats following actual oil spills. Maximum times shown do not necessarily imply complete removal of oil, but may represent author's estimate of persistence or termination of study. (CEQ Report, OCS Oil and Gas - An Environmental Assessment, 1974.)

oil spills can provide for an estimate of the persistance of oil in different types of substrate habitats, as illustrated in figure 52.

As previously mentioned, care must be exercised in interpre the graph. As the observed persistance relate primarily t length of time a particular investigator or a particular inv program was studying the problem. Research work can be terminated at any given time, but termination of the work do not mean that the research ceased because oil was no longer Thus the data from figure 52, must be considered as observed minimum of the persistance of oil in a given habitat.

f. Biodegradation

Micro-organisms play an important role in the decomposition of oil introduced into the marine environment. Because of th substrate specificity of oil degrading bacterias, the initial chemical composition of the oil a controls its rate of bacter degradation.

Viscosity, toxicity, water solubility and surface area are controlling factors, thus it is often uncertain whether a slow degradability reflects bacterial specificity towards a given hydrocarbon or the combined effects of the above factors. Due to the lower solubility of the higher boiling compounds, their decomposition require a direct contact between the bacteria and the oil and bacterial colonization of the emulsion interface, where the degradation rate depends primarily upon the surface to volume ratio; the toxicity of soluble fractions only allows bacterial growth in the less toxic portions of the undissolved oil (Gunkel, 1973). During the degradation process, the bacteria can produce surface active substances which lower the surface tension and contribute to the formation of oil-in-water emulsion.

It is a well established fact that the activity and multiplication of heterotrophic bacterias and subsequently the amount of oil that can be degraded is not limited by the density of bacterias at the beginning of the degradation processes, but by controlling environmental factors (Fuhs, 1961; Zobell, 1964; Gunkel, 1967). Zobell for example calculated that 3.3 kgs of oxygen is needed to oxidize 1 kg of mineral oil, or the equivalent of the oxygen content of about 400 cu.meter of sea water. Thus oxygen availability is a limiting factor, especially in confined embayments, with sluggish circulation.

Inorganic nutrients such as nitrogen and phosphate, due to their low concentrations in sea water, are another limiting factor, especially at the time of high phytoplankton productivity. Temperature is another important controlling factor; at low temperatures, the more toxic, low boiling fractions take longer to evaporate from the slick and bacterial activity is usually reduced. Psychrophylic (cold loving) bacteria, prevalent in the Arctic Sea and sub-arctic waters can degrade oil at temperatures as low as -1.1°C (Zobell, 1972).

Organisms other than oil oxidizers can also influence the degradation. Gunkel notices that, after a short time, oil degradation almost ceased and the number of bacteria dropped considerably. Microscopic examination showed the existence of large number of protozoams actively feeding on the bacterias.

Once the oil has been deposited on the bottom, the limited availability of dissolved oxygen, and incorporation of the oil within the sediment matrix, favors anaerobic degradation. Under such conditions, degradation will be much slower, being of the order of days and weeks rather than hours and days.

Recent studies indicate that by-products from microbial break down of oil can be more toxic that the original compounds. Information on that subject is as yet scant. Brown and Tisher (1969) indicate, based upon results of preliminary bioassay utilizing the spent media from microbial degradation of motor oil and naphtenic crude that the resulting water soluble fractions were more toxic to test fish than the original oil.

B. Ecological Impacts

The ecological impacts upon a marine environment such as Kachemak Bay, reflects the combined integrated effects of both whole oil and individual oil components upon all levels of biological organization: subcellular, cellular, whole organism, population and community.

To analyze the bio-physical-chemical changes brought by whole and degradation products of oil, the chemical classes of compounds that are most likely to affect organisms must be considered and the extent of the gross biological effects that can be expected ascertained.

For instance, if the effect is immediate mass mortality, even at low concentration, then the importance of subsequentde degradation of the oil must be viewed in a different context than when the effects pertain to long term, ubiquitous biological damage by chronic exposure.

The biological effects of oil can be examined by considering its main components as shown in fig. 53 (Blumer, 1969).

1. Saturated Hydrocarbons

   Low boiling n-alkenes, until quite recently, had been considered harmless to the marine environment. Marine organisms naturally synthesize n-alkenes, odd carbon chain length predominating; in marsh grass and benthic macroalgae, 21-29 odd carbon chain predominated, while in phytoplankton, 15-21 carbon chains seem to prevail (Clark, 1966; Blumer et al, 1971).

   It has been found that low boiling n-alkenes, which are rather readily soluble in water, induce at low concentrations (ppb to few ppm) anaesthesia and narcosis, and at greater concentrations (ppm) damage and kill a wide variety of animals; n-alkenes can be especially damaging to the larvae and juveniles of many forms of marine life (Blumer, 1971; Goldacre, 1968).

2. Olefinic Hydrocarbons

   The olefinic hydrocarbons, intermediated in structure and properties and probably toxicity (Blumer, 1971) are rarely present in crude oils. They are abundant in refined products, and are also produced by many marine organisms and may serve biological functions such as biocommunication.

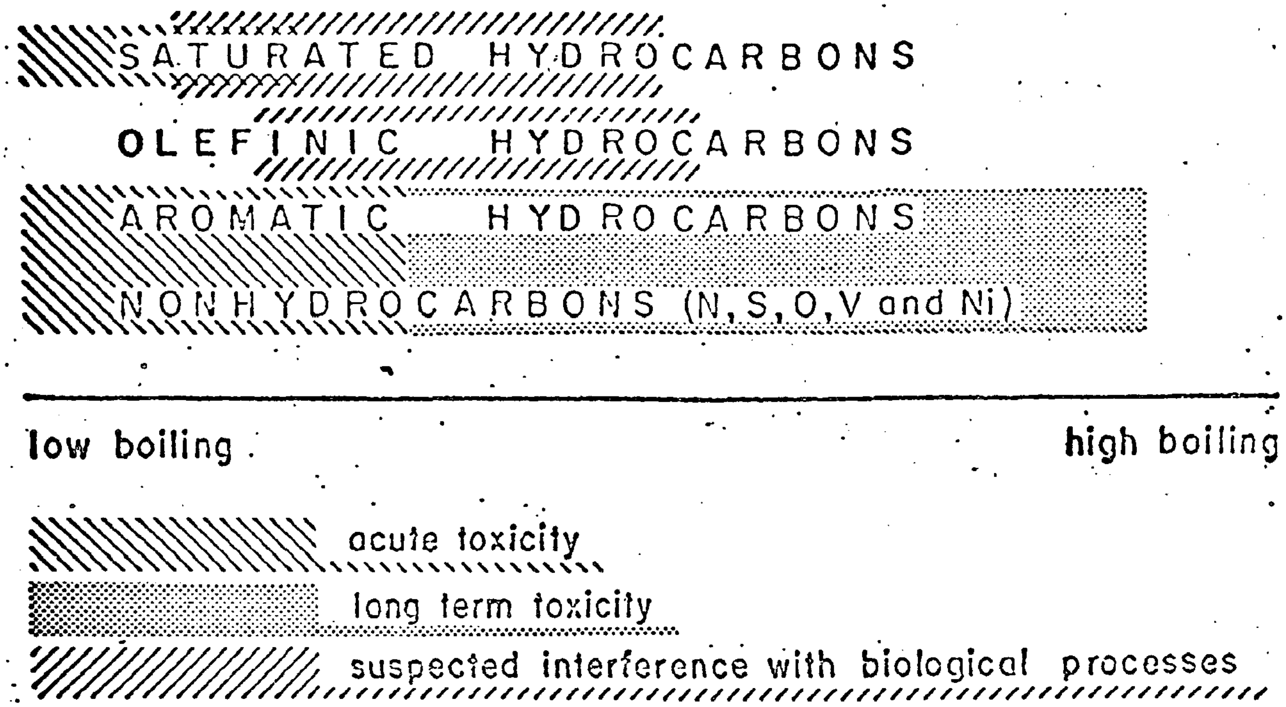


Fig. 53. Composition of Crude Oil and Toxicity of its Fraction. (Blumer, 1969)

3. Aromatic Hydrocarbons

Aromatic hydrocarbons are abundant in petroleum and represent its most dangerous fractions. Low boiling hydrocarbons (benzene, toluene, xylene) are acute poisons. They are highly water soluble and can kill aquatic organisms either by direct contact or by contact in diluted solutions.

The great tragedy of the Torrey Canyon spill was greatly compounded by the fact that the detergents used to disperse the oil had been dissolved in low boiling aromatics; their application multiplied the damage to coastal organisms. It should be pointed out however, that poisoning of marine life can occur even with non-toxic detergents, as their application disperses the toxic material from the oil, thus increasing toxic exposure through contact and ingestion.

Supporting evidence shows that toxic responses are primarily caused by the lower boiling aromatics: e.g. the comparisons of the effects of benzene, n-hexane and toluene on marine algae by Wilber (1968), the data for Various Dispersants reported by Sprague and Carson (1970), the Experiments on Gastropods by Ottway (1971); the present results of Lee et.al. (1972) on the effects of various hydrocarbons on mussels. In each of these cases, as well as others where information on the types of compounds causing toxicity is available, the low boiling, more soluble aromatics are consistantly implicated as the primary biocidal components.

The investigations of Teal and Stegeman (1973) with two oyster populations and of Brocksen and Bailey (1975) with two fish differing in lipid content, (Chinook Salmon 11% of total body fat and Striped Bass, 21% of total body fat) indicate a close relationship between concentrations of aromatics and lipid levels. Experiments on the low and high fat oyster show that, although the initial rate of uptake was the same for both groups of oysters, the animals with a lower fat content approached equilibrium more quickly than those with about twice the tissue levels.

Brocksen and Bailey, through measurement of respiratory stresses of Chinook Salmon and Striped Bass exposed to substantial concentrations of Benzene, showed that the probable physiological pathway was through absorption across the gill membrane, attachment to the erythrocytes and lipoproteins for transport into lipid rich tissues. The authors observed that the Striped Bass, with its higher lipid content, detoxified more rapidly than the Chinook Salmon; they postulated that the fish with higher lipid levels had higher concentrations of compounds needed for enzymatic detoxification of benzene and as such were able to recover more quickly.

The inference that the biological effects of aromatic hydrocarbons are more pronounced in forms with high fat/lipid contents is beginning to emerge as a factor controlling the sensitivity of various marine forms to hydrocarbons.

4. Residuals (Non-Hydrocarbons, NSO)

Residual fractions consist of high boiling hydrocarbons of all types, containing oxygen, sulfur, nitrogen and heavy metals, in the molecular weight range of 900-3000; they can represent a significant portion of the crude, up to 20%. In their behavorial and toxicity they closely resemble the corresponding aromatic compounds.

C. Biological Effects of Oil

The literature on the biological effects of oil is profuse and diverse requiring much independent interpretation to sort out some of the inherent biases of various authors. Those interested in some of the scientific polemics on the pros and cons of effects of oil spills should refer to the paper of J.G. Mackin (1973). The overall effects of oil on marine fauna and flora can be summarized as (Moore, 1973):

Effects of Direct Coating

Direct Lethal Toxicity

Sub Lethal Disruption of Physiolgcial and Behavioral Activities

Incorporation of Hydrocarbons in Organisms which may cause tainting and/or accumulation in the food chain

Changes in Biological Habitat

1. Direct Coating

Overwhelming, massive accumulation of oil, such as the 5 to 10,000 tons per mile along the shore as a result of the METULA spill, smothers all attached life.

Seabirds usually suffer most dramatically from coating by oil; birds are the most obvious organisms lethally affected by oil pollution and the impacts are usually on a sufficient scale as to affect the local, regional, and world populations. The avian most susceptible and most severely damaged by oil pollution are the auks (murres, guillemots, puffins, razor bills), diving sea ducks (scoters, eiders, goldeneyes, etc.), such birds commonly found in in great concentrations in the marine waters of Kachemak Bay and Lower Cook Inlet. Their high vulnerability to oil pollution rests with the fact that they spend most of their lives on the water, dive to collect their food and are rather weak flyers. Their reaction to disturbance is to dive rather than fly away; their pelagic habitat particularly expose them to oil pollution and if contaminated at all, they are likely to be heavily contaminated (Clark, 1973).

Toxic fractions can still be present at the time of coating, but in combination with larger amounts of heavier oil, the resulting damage can be quite less than the mortalities that can be induced by less "diluted" soluble aromatic hydrocarbon derivatives (SAD). Most sessile intertidal organisms can poke through a coat less than about a centimeter thick; thick, long lasting coat smothers the organisms.

2. Direct Lethal Toxicity

Much of the existing literature on direct lethal toxicity deals with "bioassays" on individual species; results are usually reported as of LD_{50}, the hydrocarbon cencentrations which would produce a 50% mortality within a given period of time (24, 48, 96 hrs.). However, the explicit comparison between various "bioassays" usually ends there (Moore, 1973).

Researchers rarily use identical experimental methods, or even the same petroleum product. The concentrations of hydrocarbons dissolved in water are rarely measured (especially the biocidal fractions) and the experimental laboratory conditions are usually quite dissimilar to those of the natural habitat.

Far worse, are the many experiments in which the test substance is either not identified or only vaguely described as "oil" and where the results refer to the test organisms as being "very sensitive" or "moderately resistant".

A common ground for comparison however exists (Moore, 1973). Table 23 lists the percentages of various oil products which go into solution, and the percentage which is SAD. Using this information, it is possible to critically evaluate and normalize various experimental data. Table 24 (Moore et al, 1973) summarizes estimates of the minimum toxic concentrations for a number of different classes of organisms; the evidence is fragmentary, hence the uncertainty factor of ten.

Larval stages appear to be considerably more sensitive than adults (Portmann and Connor, 1968). Larvae are affected by toxic concentrations as low as 0.1 ppm. Most adult marine organisms are sensitive to SAD in concentrations of 1 ppm or less; toxicity usually occurring in the 10-100 ppm concentration range (Mironov, 1970, Smith, 1968). In general, crustaceans and burrowing animals are most sensitive, fish and bivalves moderately sensitive, gastropods and some macrophytes least sensitive.

Table 23.
Estimated % of Composition (by weight) and Comparison of Solubilities for Various Petroleum Substances

FRACTION	DESCRIPTION	(Heavy) Crude A	(Medium) Crude B	#2 Fuel OIL	KEROSENE	RESID.
1	Low Boiling Paraffins	1	10	15	15	0
2	High Boiling Paraffins	1	7	20	20	1
3	Low Boiling Cyclo-Paraffins	5	15	15	20	0
4	High Boiling Cyclo-Paraffins	5	20	15	20	1
5	Mono- and Di-cyclic Aromatics	2	5	15	15	0
6	Polycyclic Aromatics	6	3	5	2	1
7	Naphtheno-aromatics	15	15	15	8	1
8	Residual	65	25	-	-	96
Estimated Maximum % of Soluble		10	30	60	65	1
Estimated Maximum % Soluble Aromatic Derivatives		.1-10	.1-10	1-30	1-20	0-1
Reported % Soluble Aromatics Obtained in Seawater Extracts		.1	.01		.01	

Summary of Toxicity Data

Table 24.

Class of Organisms	Estimated Concentration (ppm) of soluble aromatics causing toxicity	Estimated amount (ppm) of Petroleum substances containing equivalent amount of aromatics	
		#2 Fuel Oil	Fresh Crude
Flora	10-100	50-500	$10^4 - 10^5$
Finfish	5-50	25-250	$10^4 - 10^5$
Larvae (all species)	0.1-1.0	0.5-5	$10^2 - 10^3$
Pelagic Crustaceans	1-10	5-50	$10^3 - 10^4$
Gastropods (snails, etc.)	10-100	50-500	$10^4 - 10^5$
Bivalves (oysters, clams, etc.)	5-50	25-250	$10^4 - 10^5$
Benthic Crustaceans (lobsters, crabs, etc.)	1-10	5-50	$10^3 - 10^4$
Other Benthic Invertebrates (worms, etc.)	1-10	5-50	$10^3 - 10^4$

3. <u>Sub-lethal Effects</u>

Marine organisms depend upon a complex set of behavioral characteristics to maintain normal life patterns; many of these, especially orientation, feeding and reproduction, involve communication based upon chemical cues or pheromones. Chemical communication has been extensively studied in insects; only recently has significant attention been given to marine animals pheromones.

It was a well known fact that the lobster (Homarus americanus) can be attracted by kerosene soaked bricks. Todd et al (1972) have shown that pheromones play a significant role in regulating reproductive and social behavior in aquatic organism. Marine organisms have been found to detect food or preys through chemoreception of specific compounds in the parts per billion range. Todd et al (1972), Hasler (1970) indicated that feeding, reproduction and social behavior in marine organisms can be disrupted by SAD concentrations as low as 10-100 ppb.

The full implication of disruption of chemical communication by very low concentrations (ppb) of dissolved hydrocarbons is uncertain at this time.

4. <u>Incorporation of Hydrocarbons in Organisms</u>

Tainting and accumulation of hydrocarbons in organisms tissues occur in almost all marine species. Essentially, any aquatic organism can be expected to equilibriate chemically with its surrounding media.

At 5-50 ppm of hydrocarbons, animal tissues develop an objectionable taste (McKee and Wolf, 1963). Burns and Teal (1971) reported that #2 fuel oil spilled in a salt marsh was incorporated into nearly all organisms in the marsh ecosystem. Very small concentrations of hydrocarbons can produce tainting.

Polycyclic aromatic hydrocarbons (PAH) are widely distributed in the ocean (Zobell, 1971); they are found in the residual fractions of all crude oil and are readily absorbed in the gut of marine organisms, the metabolic breakdown of these compounds in the bodies of animals is slow. PAH have been shown to be highly carcinogenic.

5. Changes in Biological Habitats

The incorporation of oily constituants affects the habitat and disturbs, inhibits or prevents organisms to function normally. Intertidal and sub-tidal habitats are of prime concern. The amount and composition of oil that would inhibit or prevent any given organism to utilize the substrate of such habitats is unknown. Oil introduced into the sediment will leach and degrade slowly. Available toxicity data show that low to medium boiling point aromatic hydrocarbons, in concentrations as low as 10-100 ppb may be chemically offensive to virtually all species. As previously discussed, the effects of habital alteration by oil can persist for minimum periods of 3 to 10 years or more, depending upon the type of habitat.

Overview of Oil Spill Impact Upon Kachemak Bay

The salient impacts of spilled oil upon Kachemak Bay are summarized on the following chart (Fig.54).

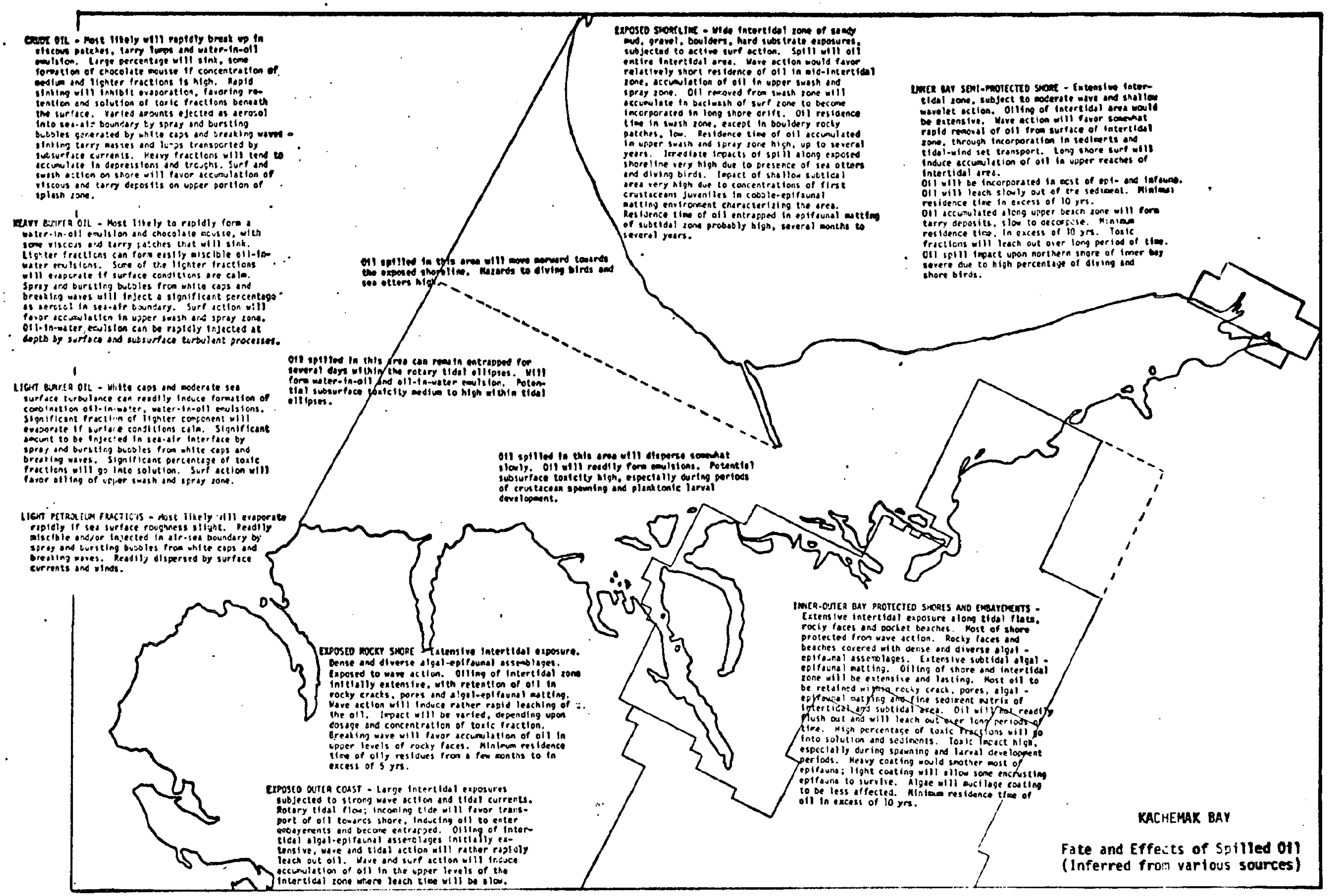


Fig. 54 - Potential impacts of an oil spill upon Kachemak Bay

SECTION IV

CONSERVANCY AND PROTECTION OF THE RENEWABLE ENERGY RESOURCES OF KACHEMAK BAY

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CONSERVANCY AND PROTECTION OF THE RENEWABLE ENERGY RESOURCES OF KACHEMAK BAY

Kachemak Bay is aesthetically invigorating, biologically rich and prolific and endowed with a diverse spectrum of renewable (fish, crabs, shrimps, clams, waterfowl, trees) as well as non-renewable (sand and gravel, perhaps oil and gas, peat and coal) resources, all actively sought for profit and pleasure by man.

The basic controversy about Kachemak Bay revolves around various concepts for the use of its natural resources. The following two articles, one from the magazine "Science" and the other from the "Anchorage Times" expressing different points of view, opinions and philosophies, rather well summarize the issues.

Polemics aside, the articles underscores a most important factor in the evolving Kachemak Bay controversy. Initially, the Kachemak Bay issue was was purely a state problem. Since the U.S. Supreme Court ruled that the greatest portion of Lower Cook Inlet is in federal ownership, thus readily opening the Lower Cook Inlet sea floor to OCS oil and gas leasing, the Kachemak Bay issue has assumed totally new dimensions. Environmentally, Kachemak Bay cannot be segmented from Lower Cook Inlet; the need to consider Kachemak Bay - Lower Cook Inlet as an environmentally integral unit is critical.

While differing, the following articles underscore differing concerns for a basic human need, that of energy. Seemingly overlooked by the writers however, is that, while under the guise of either fisheries or oil and gas, both refer to two basic forms of energy vital to man's survival:

IV-2

Offshore Drilling: Fishermen and Oilmen Clash in Alaska

Anchorage. Efforts by a group of Alaska fishermen to invalidate a state offshore lease may offer a preview of what's ahead for offshore oil and gas leasing in general. At the same time, the fishermen's protest has opened a window onto the bureaucratic process by which at least one oil-rich state sells its hydrocarbons.

The fishermen are fighting in state court and in the political arena to void a December 1973 sale of oil and gas leases on 98,000 acres in the lower Cook Inlet Basin. The sale brought the state a total of about $25 million. Included in the leased acreage were portions of Kachemak Bay totaling less than 5,000 acres. This is the focus of the conflict.

Kachemak Bay, near the mouth of Cook Inlet, is acknowledged to be one of the most biologically productive bodies of water in the nation, and perhaps the world. Although relatively small, the bay is among the most important breeding grounds and most productive fisheries in Alaska. The annual first wholesale value of the bay catch exceeds $7 million. The catch includes all five species of salmon, three species of crab, and at least two species of shrimp, as well as herring and halibut. There are also major sport fisheries for all the commercial species. In addition, tourists and residents dig thousands of buckets of clams from the intertidal flats every year.

The waters near the mouth of the bay appear to be part of an unusual circular current system that concentrates food and holds shrimp and crab larvae through several molts.

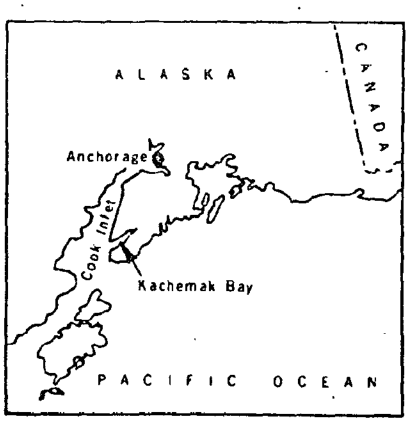
This gyre phenomenon has been known since at least 1968, when the Bureau of Commercial Fisheries (now the National Marine Fisheries Service) began a research program in the area. As a result of that and other research it became clear that the area serves as the major shellfish breeding ground for Cook Inlet and at least part of the Gulf of Alaska.

But the fishermen say that the state simply ignored the scientific evidence about the bay's importance. And they say they were routinely misinformed about the proposed lease, were not allowed to comment in a meaningful way, were denied a public hearing, and did not even know for sure that the bay would be included in the lease area until 2 weeks before the sale and long after the go-ahead decision was made.

For their part the companies that leased bay lands, notably Shell Oil and Standard Oil of California, argue that the fishermen's suit is "estopped" by an arcane doctrine known as "laches." In effect, this doctrine says that regardless of the merits of the suit it was filed too late and therefore is invalid. In addition, the companies say they have spent "considerable" sums on exploration and planning for Kachemak Bay drilling. Voiding the leases, they say, would cost them far more in real damages than any potential damage their activity might do the fishermen.

This May an Alaska District Court judge agreed with the companies' position and refused to hear the fishermen's case. Anchorage lawyer Warren Mathews is appealing the narrow legal ruling to the Alaska Supreme Court and expects a ruling within "about 6 months." Mathews represented fishermen from Cordova, Alaska, in their fight against the trans-Alaska pipeline. Ultimately an act of Congress was needed to overturn court decisions he won delaying construction of the line.

Ironically, the newly elected governor, Jay Hammond, may have doomed the fishermen's cause by espousing it in his campaign. Last fall Hammond, campaigning as a "conservationist," encouraged the fishermen in their fight and made a major campaign issue out of state leasing policies that led to the Kachemak Bay sale. Support for the fishermen has been credited as one of the main issues responsible for Hammond's narrow election victory. (He won by 285 votes.) Now he says, "I feel like a soldier who fires his artillery, charges forward to the enemy trenches, takes the position, and then discovers his shells haven't arrived yet."



Kachemak Bay is the contested area.

In adopting the issue, Hammond may have inadvertently contributed to the late filing of the lawsuit. Affidavits in the court record indicate that Hammond's chief lieutenant several times counseled the fishermen to delay their lawsuit, apparently to keep the question alive for a campaign issue.

A deposition filed by one of the plaintiffs says that Bob Palmer, a former state senator and now Hammond's chief of staff, advised against filing the suit just 2 months after the lease sale. Again at a meeting in August 1974 at the Hammond campaign headquarters in Anchorage, according to the deposition, Palmer said, "... the Kachemak Bay mess would be cleaned up if Jay Hammond were elected. ..." Some of the fishermen feel they were sold out and community bitterness against the political process is mounting.

Besides the strictly political aspects of the situation, the fishermen say that the bureaucratic process the state uses to lease oil and gas lands is discriminatory, fails to take important information into account, and is so informal as to be irrational.

During pretrial investigations evidence surfaced which indicates that the leasing process, not too unlike the federal procedures, is a series of official "Catch-22's."

Twenty months before the December 1973 lease, the Alaska Department of Natural Resources decided to hold a series of sales in the lower Cook Inlet Basin. Potentially, Kachemak Bay would be included in this area, so officials from the nearby town, Homer, wrote seeking information about possible bay leasing. They were regularly told by state officials that interest in the bay was "slight" and chances of leases therefore "small." Therefore, local officials were told they needn't seek further information.

Public Hearing Refused

Finally, 8 months before the lease, the head of the Homer Chamber of Commerce wrote to the director of the state minerals division complaining that it was impossible to get information on potential lease sales because the decisions about which lands to offer were made through a closed process. Industry nominates lands it is interested in leasing and the state chooses lands from among those nominated for the actual sale. There was, he said, no provision for public input.

Somewhat incongruously, the state minerals director wrote back saying that the proper time for "appropriate" public comment was after nominations were taken and before the sale was announced. It was never made clear how the public, not privy to the semisecret dealings between government and industry, was to know when the proper time arrived.

Early in August 1973 the Homer city manager wrote again to the state minerals chief seeking further clarification of Kachemak's status in the leasing program. On 22 August the minerals director wrote back saying, essentially, "we don't know exactly what areas will be included, but we expect little interest in Kachemak Bay." Less than a month later he wrote to the commissioner of natural resources recommending a sale to include Kachemak Bay in December 1973. On 19 October, the commissioner, after reviewing the plan with then Governor William Egan, gave his approval for the sale.

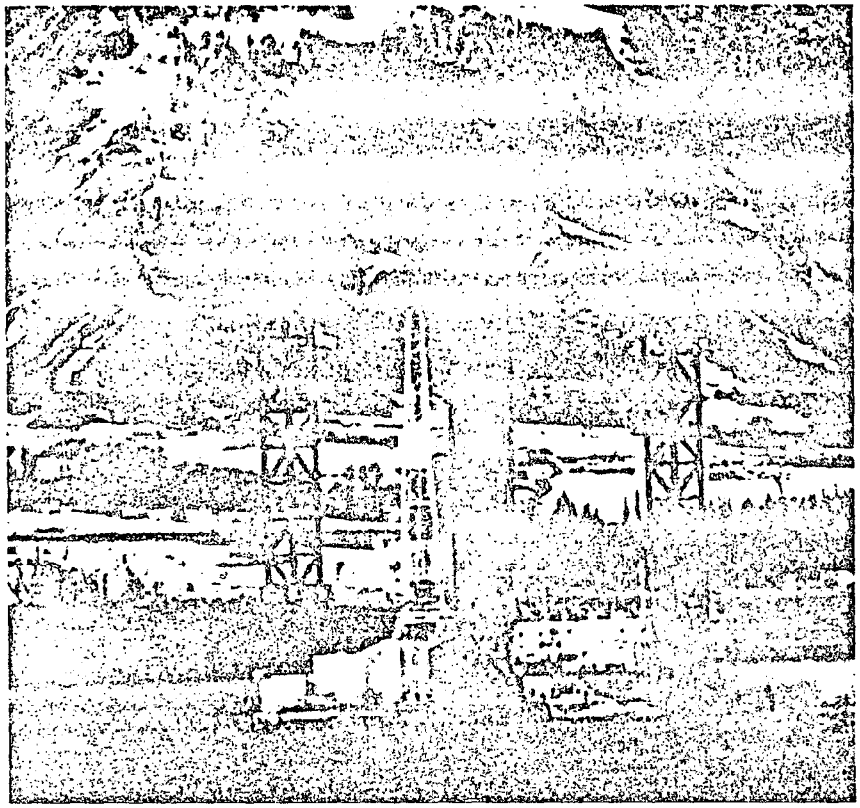
Two weeks before the 13 December sale date area residents felt they finally had concrete information that a sale was to be held and sought a public hearing on it. A petition drive garnered 275 signatures. But state officials refused to hold the hearing because the lease process was too far along and it was too late for public input. Besides, they indicated, there were no outstanding issues in the sale that a public hearing could help resolve.

Almost as an afterthought, it seems, the State Department of Natural Resources sought information on the biological community in the bay. On 22 October Natural Resources finally asked the Alaska Department of Fish and Game (ADFG) for comment on the sale. "Due to a communication problem in our department we were very late in deciding which areas to offer," the Natural Resources memo said. It asked for comments within a week so that notice of the sale could be published the first week of November, just meeting the legal notice requirement.

The ADFG area biologist in Homer, Loren Flagg, received the memo on 29 October. He hurriedly drafted a memo to his superiors calling their attention to the importance of the bay. He said, in part:

The ADFG should seek an immediate delay of 30 days in the sale "to allow sufficient input from all state and government agencies and from the public.

"We believe, and have evidence to support our belief, that Kachemak Bay . . . is one of the most highly productive marine environments in the world. The Cook Inlet staff feels that this area should be classified as critical habitat and that no development should be allowed which would risk this extremely valuable environment."



Preparing for exploratory drilling, a "jack-up" oil rig is anchored in Kachemak Bay.

The Bluff Point area (one of the places subsequently leased) is both a "major reproductive area" and a "major rearing area" for shrimp and crab.

"Kachemak Bay harbors tremendous populations of shorebirds and waterfowl at various times of the year. The bay also has various forms of marine mammals and many other forms of marine life . . . oil development in an area so rich in life is not worth the risks involved."

But by the time Flagg was consulted his suggestions were largely too late. He thought his comments would influence the decision-making process, but actually the decision to offer bay lands had already been made. The consultation with ADFG was almost a pro forma exercise. Flagg's comments in the strong pro-oil climate of 1973 were extremely courageous. If anything he may have understated what was at stake in the bay and underestimated the potential risks from oil development.

At the isolated National Marine Fisheries Service (NMFS) field station at Kisitsna Bay, a small arm of Kachemak reachable only by light plane or small boat, Evan Haines has been doing research on the life cycle of shrimp for 4 years. As the result of extensive NMFS population studies, he is able to say that Kachemak Bay "is [far] more productive . . . than most people realize.

"On a given area basis," he says, "Kachemak Bay is at least ten times more productive than the Gulf of Mexico. We found that the production of this area is such that you can harvest about half the [shrimp] stock [per year] and still maintain the quotas which are pretty high, especially on a species that only lives 4 or 5 years."

Since 1972 Haines has surveyed the bay to determine on a three-dimensional plot where the most productive areas were. On the basis of that research he says, "we know that the drill site is located in a spot that is a very critical habitat for the larval stages. Apparently the larvae are held in there, and it has something to do with the currents.

"I speculate," he says, "that there is some type of a current holding them in. For instance, with king crab larvae you find all four stages until the settling stage in there . . . you're talking about a time from release to settling of 3 or 4 months. No organism can possibly maintain itself in an area for that length of time without some type of circular motion being involved.

"I had a series of stations," Haines says, "when I got done plotting. Without a doubt there they were [at the proposed drill site], right at that station. Not only king crab larvae, but Tanner crab and high concentrations of Dungeness crab larvae and two commercial species of shrimp as well. All of them were right there.

"I worked up the data," Haines continued, "without any knowledge whatsoever of potential drilling, and I gave the information, as we always do, to [ADFG]. They called me back the next day . . . and said, 'You know what's going on? They're thinking of drilling out there and the drill site is right at station 17.'

"They couldn't have picked a worse site," Haines says, "in regards to the biology of the bay." And he notes that larvae are "much more susceptible to any adverse environmental threats than later stages."

Working independently at Kisitsna Bay and at the main NMFS laboratory at Auke Bay, near Juneau, two other researchers seem to be confirming Haines' fears about the dangers of environmental stress, especially petroleum pollution, to shellfish larvae.

At Kisitsna Bay, Tony Micklenburg says that "at 7 ppm [parts per million] of petroleum in solution with seawater we get a complete kill of larvae." He is presently reducing the oil concentration and seeking an LD_{50} level (lethal dose needed to kill half a test population).

At Auke Bay, John Karinen, working partly under a $175,000 NMFS toxicity study funded by Shell Oil, feels that Dungeness crab larvae are even more sensitive to oil in the water. His preliminary results indicate an LD_{50} for Dungeness crab larvae of less than 1 ppm. The LD_{50} for other shellfish, he says, seems to lie in the range of 1 to 5 ppm.

But he thinks there are other significant effects on organisms from concentrations of oil far too small to kill outright. "I'm pretty sure there are behavior effects from amounts so tiny they're practically molecular," Karinen says. Possible effects include failure of an organism to mate or to release premating sex attractants (pheromones) and failure to respond to light affecting feeding and growth.

"Any spill situation," he says, "will exceed these [LD_{50}] values even at depth. A spill in Chebucto Bay, Nova Scotia, left emulsions of oil 50 meters deep in the water column and 10 kilometers from the spill site."

Industry figures seem to indicate tolerances for much higher levels of oil. One reason, he suggests, might be the way the oil is mixed into the water and the way the concentration is ultimately measured. "We mix oil into the seawater for 20 hours before we begin a test," he says. Oil values are checked by extraction, infrared absorption, and gas chromatography.

But apart from long-range dangers such as oil spills and other pollution, the fishermen see another threat from oil exploration that they think is more immediate. "We lost 40 pots out there this past year due to increased traffic, most of it due to oil work. If there's drilling out there it will wipe us out," says Rosalee "Snooks" Moore. With her husband Ken, she operates three boats that fish Kachemak Bay and occasionally Cook Inlet and the Gulf of Alaska in good weather. In addition to keeping the books, she skippers one of the boats that fishes the bay for salmon and shellfish, particularly king crab.

Crabbing Gear Lost

Pots are the tools of the crabber's trade. The pots used by Alaska crabbers are steel mesh boxes as big as 6 feet on a side. They are baited and dropped to the ocean floor but attached by ropes to a surface buoy that helps the fishermen identify and locate their own pots. An Alaska crab pot, Moore says, costs "anywhere from $450 to $600 plus the cost of up to 500 feet of heavy nylon line and the buoys."

The trouble, she says, is that careless or "ignorant" oil company workboat and tug operators run over the buoys and "they cut them right off." Without the buoys, fisherman can't locate their pots and lose them. In addition, the pots keep trapping crabs that can never be recovered, depleting crab stocks and competing with captive pots.

Last winter Shell Oil moved a "jack-up" drilling rig into Kachemak Bay to begin exploratory drilling. Moore says the rig or its towboats cut off seven of her pots in one night. "The loss for us for those pots and their product for 20 days before they were replaced was over $8000," she says. She conservatively estimated the value of the lost catch at more than $5000.

If the Moores, among the bay's highest earners, sustain comparable gear losses again next year, they fear they may be driven out of the fishing business. "Crabbing is the biggest part of our income," Moore says. "If we lose that, I think we'll have to look somewhere else. But I don't think there's anywhere else, especially with the boats we have—a 42-footer and a 56-footer. They're basically not real rough water boats, they're bay crabbers. And you don't go very far with a bay crabber—not unless you want to die."

Fishing is an expensive gamble against the elements and an uncertain market. Boats costing as much as $200,000 are not uncommon in Alaskan waters. And some families have grown wealthy fishing, with crab or salmon catches some years bringing in as much as $100,000 or more. But the brisk trade in repossessed boats indicates how thin the line is between success and failure for the fisherman.

Hit hard by rising costs for equipment, credit, fuel, and maintenance, faced with uncertain markets and catches as a result of foreign competition, the fishermen feel buffeted by forces beyond their control already. But to lose thousands of dollars worth of gear to workboats and drilling rigs infuriates them further.

When company officials come to Homer seeking to settle claims for lost gear they find an atmosphere heavy with hostility. Fishermen are driven to near frenzy, they say, when oil companies worth hundreds of millions of dollars haggle over a few thousand dollars worth of crab pots that can make the difference between making a profit and seeing a boat repossessed. An incident in which Shell promised to carry a local fisherman aboard the rig when it was moved to guide it through the fishing grounds, but then inexplicably failed to call him, poisoned the air still further.

Privately, company officials admit that the publicity from Kachemak Bay is hurting them, and some doubt that any oil strike there will be sufficient to offset that. But they also see themselves as victims of a situation that they didn't create. "We followed all the rules," says an oilman, "it's not our fault that we bid on these contested lands. The state offered them for sale."

State officials say also that they were just following well-established policies and practices for leasing oil and gas lands. "This was no different from any previous sale, and there was never any complaint before," a state official says.

In a real way the oilmen and the bureaucrats are right; there were no basic differences between the Kachemak Bay sale and its predecessors. Although the bay's richness makes it the ideal focus for a challenge, the real differences are psychological rather than physical. The fishermen of Kachemak Bay see their life and their livelihood equally under attack by forces they feel are arrogant, insensitive, and shortsighted. They have organized an angry political and legal campaign to defend themselves. At one time in Alaska and most of the rest of the United States, energy production was sacrosanct. But last fall, adopted as an election issue, the Kachemak Bay challenge touched enough voters to play a major role in electing a "conservationist" governor. Although the ultimate fate of this challenge will be decided in the courtroom, it seems clear that the fishermen of Kachemak Bay have already influenced future state sales and possibly federal sales as well.—MARK PANITCH

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OCT 26, 1973 Anch. Times

Kachemak Bay Lease Sales

By Thomas E. Kelly

(EDITOR'S NOTE: No subject is more controversial in Alaska today than the utilization of the state's natural resources. And no figure on the state scene is more outspoken on the subject than is Thomas E. Kelly, former state commissioner of natural resources and now a consultant in earth sciences in Anchorage. To stimulate additional discussion the Times has invited Kelly to write a series of weekly columns on Alaska's resources. This is the first).

KACHEMAK BAY is a magnificent geographic gem. For those unfamiliar with its deep azure blue waters, the bay extends 30 miles eastward from its confluence with lower Cook Inlet. It is endowed with some of the most spectacular scenery of any inland bay in the state. The south shores are popular recreational areas for many Anchorage residents who enjoy the magnificent surroundings of Halibut Cove, Seldovia Bay and the marshalands of the Fox and Bradley Rivers at the head of the bay.

Homer, the picturesque community on the north shore of Kachemak Bay, is at the terminus of the Sterling Highway on the Kenai Peninsula. Homer is potentially a superior port to Anchorage and has one of the best deep water anchorages in Alaska. The community has only two basic natural drawbacks to making it a Balboa of Alaska — fresh water and a plentiful supply of clean, inexpensive fuel.

Kachemak Bay is well known for its crab and shrimp fishery that has been billed as "fabulously productive" — somewhat of a misleading statement since the catch quota of shrimp and king crab allowed by the Alaska Department of Fish and Game amounts to about 5 per cent of the state total of these high dollar market seafood products.

IN RECENT years there has been little exploratory activity in the vicinity of Homer. During the period 1960-66 six wells were drilled within 15 miles of the city. Five wells were dry holes and one resulted in the discovery of a small gas field that has remained shut-in for 10 years because of lack of market and questionable economic value.

In 1966, Texaco, Inc. drilled the Cold Bay State No. 1, an offshore exploratory test located in Kachemak Bay five miles northeast of the city. The well was drilled in 11 days and was abandoned as a dry hole. The activity occurred with virtually no public attention but if attempted today the wrath of every environmentalist in the state would be invoked.

Oil and gas lease sales in Kachemak Bay are nothing new either, but are interesting if only from a historic standpoint. At the first competitive state lease sale held on Dec. 10, 1959, several tracts of offshore lands in the bay were offered and leased to local Anchorage businessmen.

In December 1961 the state offered tracts of tide and submerged lands in Kachemak Bay and received bonus bids of about $1 million for seven tracts. Again at the 16th competitive oil and gas lease sale in July 1966, the state offered and leased offshore tracts lying immediately west of the Homer city limits.

The lease sales went virtually unnoticed and there was never any indication of conflict — that is, until the 28th competitive sale in December 1973. Partly because of the Arab oil embargo and uncertain fate of Middle East oil holdings of multi-national oil combines, some large oil companies went berserk and bid $25 million dollars for tracts of offshore land at the mouth of the bay, adjacent to what the U.S. Supreme Court has ruled are federal OCS lands.

background — now for the problem.

Following the sale in 1973, certain oil industry representatives, who perhaps were not the world's best salesmen, attempted to explain to local Homer residents, including fisherman, the program for exploration operations on the recently acquired leases. Spurred on by what Homer's Mayor Hazel Heath has described as "an itinerant hippie who doesn't work anymore than he has to" and "a Florida courthouse lawyer who never baited a hook in his life," some of the area's fisherman loudly denounced the sale and filed suit to have the leases voided.

The state Superior Court dismissed the complaint on a "laches" basis for not being timely filed, and the case is now on appeal to the state Supreme Court.

In the meantime, the governor and members of his cabinet from time to time issue official statements that the lease sale was a tragic mistake that the previous administration committed and that the current administration hopes to encourage the forthcoming legislative session to pass a bill cancelling the leases. This is somewhat of a paradox since the state is the defendant in the lawsuit on appeal and is by inference, if not by direct action, urging the Supreme Court to rule against the state. Normally when the soverign is a defendant in litigation it does not try its case in the newspapers, particularly when the potential cost to the taxpayers is about $50 million; that is, if the state loses and rebates all bonus, lease rentals and costs incurred by the leasees.

But far more damaging than loss of dollars is the precedent of encouraging and abetting abrogation of property rights established by binding legal contract.

THE FOUNDATION for cancellation of the leases is based on the premise that oil operations will endanger the fisheries or that resulting developments, in event of discovery, will mar the esthetic beauty of Kachemak Bay.

The state has passively acquiesced to leasing and attendant exploration of federally controlled waters of lower Cook Inlet, the boundary of which is 1¼ miles from the proposed first test well on the state offshore leases.

The department of fish and game has classified much of [illegible] areas are managed for the protection of the animal or plant dependent on the area for propagation and other uses, if permitted at all, are subject to special restrictions.

While there are valid biological and ecologic reasons for protecting a breeding ground for crab, the boundary of the area is surely not pinned down to an arbitrary line adjacent to which oil exploration is allowed but immediately across the line activity would destroy the fishery.

If anyone cares to trace the whereabouts of king crab in the bay today he will find that the crab moved out since the end of August and are located somewhere in the lower Cook Inlet waters under federal jurisdiction. If that areas is leased and someone starts to drill, one hopes the crab will have enough "smarts" to hustle back to the sanctuary on state land.

On esthetics, if an offshore production platform on state land is offensive to the viewer from Bluff Point on the hill above Homer, why is it not just as offensive on federal lands 1¼ miles to the west?

THE FINAL incongruity is economic. If production is established on federal leases abutting state lands and the producer starts draining oil or gas from under state lands what happens? Are the resources of the state drained away with no benefits to its stockholders — Alaskan citizens — or does the state change its mind and hold another sale at that time to protect against drainage? And what about the crab then?

Like the Flying Dutchman, a silhouetted vessel in the fog with no one at the helm, the state administration creates the problem and resolves none. A balance between environmental concerns and development seems harder and harder to achieve.

There seems to be little effective management of resources in Alaska at a time when the state is drowning in red ink. Perhaps the best solution is to allow those most directly affected — the crab, the crab fisherman and the oil industry — to work out a compatible solution. I bet it can be done with far less pain and strain than now continues under the reins of bureaucracy.

1. Energy to perform mechanical work and provide for creature comfort (oil, natural gas, electricity, coal, atomic fission).
2. Energy to sustain vital life processes (food stuff).

Thus the various Kachemak Bay resource development and utilization issues can be synthesized within a common concept of planning, management, protection, conservancy, development and use of renewable and non-renewable energy resources. This portion of the document addresses itself to the aspects of conservancy and protection of the "renewable energy resources" (living resources) essential to man's life support.

The sustenance of "renewable energy resources" is totally dependent upon the prime integrity and quality of the supporting environment or ecosystem. Ecosystems can be considered as being renewable and non-renewable.

A renewable ecosystem can be characterized as one within which the dynamic equilibrium between diverse interacting processes is maintained in its natural balance. The equilibrium is dynamic, in that nature in its constant state of unrest, will impose transient disturbances upon the system; but the time scale (geological rather than human) and rate of occurrences of such disturbances is such however, that they are readily assimilated within the spectrum of natural variabilities without disrupting the overall dynamic equilibrium between interacting processes.

Of late, many allusions have been made on how nature itself "pollutes". It is undeniable that severe and at time cataclysmic events, can overwhelm segments of biological populations and induce mass kills. The demise of a number of individuals however is not an indication that the ecosystem itself has been severely damaged, but that a transient event has temporarily disturbed the equilibrium of a segment. Once the disturbance is over, the system re-establishes itself quickly. It must be noted that, as a rule, many of nature's disturbances are physical or geochemical, through release and intrusion of components in an elemental state readily compatible with the geo-chemical "assimilative capacity" of the natural system.

A "non-renewable" ecosystem can be characterized as one in which the dymamic equilibrium between the natural processes is being continuously disturbed and/or altered by either attrition of the "lebensraum" (vital space) required to maintain biological populations, destruction through excessive harvest or overprotection of "desirable" species, or intercompetition between diversity of species, or introduction of ever increasing quantities of unnatural compounds which readily react with, disturb, alter, block, obstruct natural biological processes; under such condiditons, nature has lost its ability to "assimilate" and the usually reversible biological changes are taking place on a "human time" scale (a few decades) rather than a geological time scale (many decades to centuries). Under such conditions, except perhaps for bacteria and other more primitive forms of life, the bulk of the biological systems cannot benefit from natural selection and evolutionalry processes to compensate for rapid and drastic changes in environmental quality. The true meaning of "pollution" resides in this fact.

The conservancy and protection of the renewable energy resources of Kachemak Bay (and Lower Cook Inlet) can be pursued by:

1. Setting aside an area within which the sustenance of life processes will be given dominant priority and only other "compatible" uses of the environment will be tolerated (e.g. Critical Habitat).
2. Imposing strict technical and environmental controls upon "non compatible" uses of the environment to minimize to the utmost the life damaging direct and indirect effects of conflicting resources uses. (i.e. anti-pollution measures, application of best technology, strict operational controls and enforcement).

KACHEMAK BAY CRITICAL HABITAT

As a result of the environmental/fisheries/oil and gas leasing controversy, the legislature established in 1974 as the "Kachemak Bay Critical Habitat", the entire marine waters area eastward from a line drawn between Anchor Point and Point Pogibshi. The establishement of the Critical Habitat expressed, in broad terms, the concerns to protect the area from uncoordinated and potentially uncompatible resources use.

Prior to the establishment of the Kachemak Bay Critical Habitat, a number of actions had already been taken to maintain and protect already well recognized biological and environmental values of the area:

1. Incorporation of the Sheep Creek - upper Fox River drainages into the Kenai National Moose Range
2. Creation of the Fox River Critical Habitat (1972)
3. Creation of Kachemak Bay State Park (1970)
4. Creation, through Commercial Fisheries Regulatory Stipulations (S AAC 21.750 - Closed Waters) of the Bluff Point Crab Sanctuary (1970)

All above actions reflect the intent to protect and maintain the environmental and biological attributes of the area.

To project the purpose and significance of a Critical Habitat, within the intent of a conservancy and protection spectrum of actions, the statutory definition of the Critical Habitat and the statutory obligations of the Alaska Department of Fish and Game, as the agency responsible for the administration and protection of the Critical Habitat, needs to be underscored.

"Critical Habitat" as defined under Article 5 of Title 16 (Fish and Game) reads as follows:

Article 5. Fish and Game Critical Habitat Areas.

Sec. 16.20.220. Purpose. The purpose of §§ 220—270 of this chapter is to protect and preserve habitat areas especially crucial to the perpetuation of fish and wildlife, and to restrict all other uses not compatible with that primary purpose. (§ 2 ch 140 SLA 1972)

Sec. 16.20.240. Regulations. The board shall promulgate regulations it considers advisable for conservation and protection purposes governing the taking of fish and game in state fish and game critical habitat areas. (§ 2 ch 140 SLA 1972)

Sec. 16.20.250. Multiple land use. Before the use, lease or other disposal of land under private ownership or state jurisdiction and control, within state fish and game critical habitat areas created under this chapter, the person or responsible state department or agency shall notify the commissioner of fish and game. The commissioner shall acknowledge receipt of notice by return mail. (§ 2 ch 140 SLA 1972)

Sec. 16.20.260. Submission of plans and specifications. When the board so determines, it shall instruct the commissioner, in the letter of acknowledgment, to require the person or governmental agency to submit full plans for the anticipated use, full plans and specifications of proposed construction work, complete plans and specifications for the proper protection of fish and game, and the approximate date when the construction or work is to commence, and shall require the person or governmental agency to obtain the written approval of the commissioner as to the sufficiency of the plans or specifications before construction is commenced. (§ 2 ch 140 SLA 1972)

In order to better emphasize the management, protection and enforcement functions of the Alaska Department of Fish and Game with respect to a "Critical Habitat", several important statutory functions and requirements must be underlined.

First, under the functions of the Commissioner:

> **Sec. 16.05.020. Functions of commissioner.** The commissioner shall
>
> (1) supervise and control the department, and he may appoint and employ division heads, enforcement agents, and the technical, clerical, and other assistants necessary for the general administration of the department;
>
> (2) manage, protect, maintain, improve, and extend the fish, game and aquatic plant resources of the state in the interest of the economy and general well-being of the state;
>
> (3) have necessary power to accomplish the foregoing including, but not limited to, the power to delegate authority to subordinate officers and employees of the department. (§ 4 art I ch 94 SLA 1959; am § 1 ch 110 SLA 1970)

The language of Part 2 of Sec. 16.05.020 is of special interest, as it specifically refers to the Commissioner's responsibilities towards both the <u>fish and game</u> and <u>aquatic plant</u> resources of the State.

To clearly underscore the scope of the Alaska Department of Fish and Game duties, the statutory definitions of fish, game, and aquatic plants must be stressed.

> **Sec. 16.05.940. Definitions.** In this chapter
>
> (6) "fish" means any species of aquatic fin fish, invertebrates and amphibians, in any stage of their life cycle, found in or introduced into the state;
>
> (9) "game" means any species of bird and mammal, including a feral domestic animal, found or introduced in the state, except domestic birds and mammals; and game may be classified by regulation as big game, small game, fur bearers or other categories considered essential for carrying out the intention and purposes of this chapter;
>
> (23) "aquatic plant" means any species of plant, excluding the rushes, sedges and true grasses, growing in a marine aquatic or intertidal habitat;

The term Fish and Game must be viewed as an acronym encompassing all of the zooligical entities (except perhaps insects of the State). It must also be strongly underscored that, apart from what is nebulously referred to as "rushes, sedges and true grasses", the Department has statutory responsibilities for all aquatic plants (phytoplankton, thallophytes or red, brown and green algae and marine angiosperms or eel grasses).

The statutory language of Sec. 16.20.220 of Article 5 states that the purpose of Fish and Game Critical Habitat Areas "is to protect and preserve habitat areas especially crucial to the perpetuation of fish and wildlife...." What is meant by "habitat areas especially crucial to the perpetuation of fish and wildlife" is left open to many interpretations.

In referrence to the previous discussion relating to "renewable" and "non-renewable" ecosystems, the term Critical Habitat can be defined as:

> "A natural area or type of environment of sufficient size and prime quality essential to the survival, reproduction, productivity and life functions of fauna and/or flora of unique character, diversity, natural, recreational and/or harvestable value".

Two components essential if a Critical Habitat is to fulfill its intended purpose must be stressed:

1. <u>Sufficient Size</u>

   Adequate space, or in the case of the marine environment, a sufficient volume of marine waters, is most essential to the sustenance of the biological functions of diverse interacting biological entities, many of which range in and out or migrate through the area.

Insuring an adequate size or volume for a Critical Habitat to perform its intended function is usually one of the more difficult and demanding aspects of defining and legislating the creation of a Critical Habitat.

As presently defined, the Kachemak Bay Critical Habitat has the surface area and volume of water requisite to function satisfactorily. It is interesting to note that, based upon biological considerations for the protection of crab spawning area, ADF&G initially requested an area extending further into the open waters of Lower Cook Inlet.

2. Prime Environmental Quality

Prime environmental quality is a most essential requirement to the effective performance of a Critical Habitat. A Critical Habitat cannot withstand heavy, and especially incompatible human use. Because of the present intensity of commercial fishing, the increasing volumes of urban and vessel discharges, use of part of the area as log storage and log transfer, the increasing use of the protection afforded by the Bay for marine salvage and repair, the increased small boat traffic, the increase in ocean going traffic, a good portion of which consists of tankers carrying loads as great or greater than the amount of crude spilled by the METULA, the prime environmental quality of Kachemak Bay is already under stress.

The longevity of the Kachemak Bay Critical Habitat and its intended function to maintain the environmental/biological attributes and productivity of the Bay must also be viewed within the context of Article VIII

(Natural Resources), Section 4 of the State of Alaska Constitution, especially the last six words:

> **Section 4. Sustained Yield.** Fish, forests, wildlife, grasslands, and all other replenishable resources belonging to the State shall be utilized, developed, and maintained on the sustained yield principle, subject to preferences among beneficial uses.

The creation of the Kachemak Bay Critical Habitat must be considered as statutory recognition of its environmental and biological worth to the citizens of the State; conservancy and protection of its prime values must be such that the intended course of action by the legislature does not become prostituted by shortsighted actions governed by: "subject to references among beneficial uses", but instead that the course of action be carried out within the full meaning of Sec. 16.20.220:

> "To restrict all other uses not compatible with that primary purpose".

The basic question then arises, can "other uses" be so planned, engineered and controlled as to be "compatible with that primary purpose" (e.g. development of oil and gas resources in a highly productive fishery area).

Present statutory, regulatory and enforcement authorities of the state agencies (e.g. Department of Natural Resources, Department of Environmental Conservation, Department of Fish and Game) as well as of federal agencies (e.g. Corps of Engineers, Environmental Protection Agency, U.S. Geological Survey, National Marine Fisheries, Fish and Wildlife Service) are, if properly coordinated, formulated and applied, and enforced already sufficient to maintain and protect the quality and productivity of the environment of the Bay.

The next basic question then is, in view of the availability of large bodies of laws and regulations, how effective are the current agencies' practices in the effective imposition and enforcement of environmental protection measures so that "other uses" are indeed "compatible with that primary purpose".

Environmental Protection, How Effective

Safeguard of environmental quality is the major concern that must be accomodated if the public is to be persuaded that the oil and gas resources of Kachemak Bay and Lower Cook Inlet can be developed with as close to zero risk as possible. Developing the oil and gas resources is a hazardous undertaking; environmentally damaging accidents can occur during any of the four major phases of exploring, developing, producing and transporting oil and gas.

At present, in the absence of any drilling, transportation of petroleum over the waters of Lower Cook Inlet - Kachemak Bay, poses the greatest hazard to the environment. Petroleum capacity of the tankers plying through the area range between 120,000 and 500,000 barrels; the METULA incident spilled about 250,000 or so barrels, thus present tanker traffic has the potential for creating a mishap the size of the METULA.

Technological capabilities and knowhow, as well as the ability to impose effective environmental protection measures is readily available. However, how well such technical knowhow and protection is being applied needs to be critically and pragramatically examined.

Effectiveness of environmental protection technological and regulatory practices can be gauged from two points of view: (1) ability to apply the highest level of technological control at the source and (2) imposition and enforcement of environmentally effective protection measures.

1. Control Technology at the Source

A comprehensive discussion of the adequacy of OCS technologies can be found in Chapter VI of the University of Oklahoma document titled "Energy Under the Ocean". The document comments upon the fact that, until recently, oil and gas offshore technologies were geared primarily to satisfy the interests of the petroleum industry and regulatory agencies. Now, however, environmental concerns have changed the criteria used in determining what is satisfactory, and as a result, when evaluated on the basis of these new criteria, many of the operational standards, procedures and technologies are found to be most inadequate.

The dominance of the industry in the preparation of operational stipulations, safety and anti-pollution guidelines (e.g. USGS OCS Orders) and the permisiveness of responsible regulatory agencies, prompted a congressional inquiry on the appropriateness and effectiveness of responsible regulatory agencies in dealing with an industry under their control. House Report No. 93-1396, 93rd Congress, 2nd Session, published October 1, 1974, (Our Threatened Environment, Florida and the Gulf of Mexico; Committee on Government

Operations, 19th Report to 93rd Congress, based upon study made by the Conservation and Natural Resources Subcommittee), analyzes and discusses the salient problems. In its finding the report states that:

> "The studies have shown that there is a considerable body of federal laws to deal with environmental problems such as _ _ _ _ to prevent and reduce the adverse effects of OCS oil and gas and mineral development on coastal waters and onshore _ _ _ ".
>
> "However, these studies have also shown that, in many cases, the federal agencies charged with the duty to use this body of law economically and efficiently have failed to do so".

A most important facet, when considering how effective point source controls are imposed upon offshore oil and gas operations is reflected in the committee findings that:

> "The Survey (USGS) is placing too heavy reliance on industry committees to implement recommendations aimed at solving OCS safety and anti-pollution problems".

The house document indicates that as late as April 1974, the formulation and revision of the various OCS orders which the USGS promulgated to regulate the offshore activities of the industry were mostly a by-product of industry - government cooperative procedures that excluded the public until the orders were acceptable to both the industry and the Survey.

The USGS, in August 1974, indicated that three joint GS-API (API is a national trade association representing all branches of the petroleum industry) committees are now dealing with OCS safety and anti-pollution problems. Each committee, each with several "task groups" is headed by a representative from the industry. Each committee has at least one GS representative, but several of the task groups do not have GS representation. There is no representation on these joint committees from outside organizations or the public.

The house document also states that when the survey was queried about whether these joint industry committees, formed at the request of USGS, were subject to the Federal Advisory Committee Act of October 6, 1972, the survey indicated that the GS-API joint committees did not fall under the requirement of the act. The house document then states that:

> "The survey dependence on these joint committees is misplaced _ _ _ _ the joint GS-industry committee procedures gives the industry a significant and perhaps dominant role in the survey's standards setting and R & D program, no similar opportunity is provided to any other groups or the general public".

The house document serves to focus upon past and still current industry - agency procedural practices. Without an appropriate technically independent and knowledgeable body of professionals capable of evaluating the technological worth and effectiveness of predominantly industry generated specifications and standards, the question of how well environmental protection controls at the source can be imposed and enforced remains unanswered.

An example of how deficient technology is permitted to operate in the rigors of Alaska's OCS waters, is provided by the recent tribulations of the drilling vessel "Glomar Conception", in the N.E. Gulf, off Yakataga. The ADF&G, in its comments on the proposed "Strat-drilling" operations, queried the USGS about their involvement in ascertaining the adequacy of a multi-moor drilling platform as compared to a much more stable semi-submersible platform to drill at the site. USGS reply was that the agency relies upon the industry to provide what the industry considers to be appropriate and that the drilling vessel was deemed adequate based upon past on station performance in the North Sea. The shortcomings and failures of the platform to complete the task are history. The case of the Glomar Conception, perhaps best illustrates what can be considered as a very thin margin of environmental safety at the operational site, due to a lack of effective check and balance between operators and regulators in the planning and use of best technology and operational safeguards.

A parallel can be made with the State of Alaska in respect to the jack-up rig "George Ferris". As yet unanswered is the responsibility of pertinent state agencies to insure that the most modern and fail safe technology is designed for operation in the rugged, unpolluted and biologically rich marine waters of

Alaska. Present, seemingly unchecked reliance on industry practices does not provide the level of environmental protection safety required in the highly biological sensitive and valuable areas of Lower Cook Inlet and Kachemak Bay.

2. Imposition and Enforcement of Environmental Protection Measures

A major aspect of the environmental protection of the marine waters of Kachemak Bay and Lower Cook Inlet rests with the protection and maintenance of the quality and productivity of such waters.

Protecting the quality of the marine waters can be approached from two different points of view: technological and ecological. The basic differences in approaches and methodologies are illustrated in Table 25. (Westman, 1972).

In terms of ultimate water quality goals sought, the technologists define their goals in terms of uses to which water is to be put by man. The current statutes defining the "Water Quality Criteria for Waters of the State of Alaska", follow the technologists' definition, as shown in Table 26.

The ecological viewpoint, by contrast, seeks to maintain protection and if so needed, restore the physical, chemical and biological integrity of the waters. The ecological viewpoint regards "pristine" or as close as possible to "pristine" conditions as providing the "balance of nature" that can insure water clean enough to meet all of man's requirements regardless of "use". The Federal Water Pollution Control Act Amendment of 1972 (PL 92-500), takes the ecological approach to the maintenance

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WATER QUALITY CRITERIA FOR WATERS OF THE STATE OF ALASKA

Water Quality Parameters / Water Uses	(1) Total Coliform Organisms (see note 1)	(2) Dissolved Oxygen mg/l or % Saturation	(3) pH (see note 3)	(4) Turbidity, measured in Jackson Turbidity Units (JTU)	(5) Temperature, as measured in degrees Fahrenheit (°F)	(6) Dissolved inorganic substances
A. Water supply, drinking, culinary and food processing without the need for treatment other than simple disinfection and simple removal of naturally present impurities.	Mean of 5 or more samples in any month may not exceed 50 per 100 ml, except ground water shall contain zero per 100 ml.	Greater than 75% saturation or 5 mg/l.	Between 6.5 and 8.5	Less than 5 JTU	Below 60°F	Total dissolved solids from all sources may not exceed 500 mg/l.
B. Water supply, drinking, culinary and food processing with the need for treatment equal to coagulation, sedimentation, filtration, disinfection and any other treatment processes necessary to remove naturally present impurities.	Mean of 5 or more samples in any month may not exceed 1000 per 100 ml, and not more than 20% of samples during one month may exceed 2400 per 100 ml, except ground water shall contain zero per 100 ml.	Greater than 60% saturation or 5 mg/l.	Between 6.5 and 8.5	Less than 5 JTU above natural conditions.	Below 60°F.	Numerical value is inapplicable.
C. Water Contact Recreation	Same as B-1	Greater than 5 mg/l.	Between 6.5 and 8.5	Below 25 JTU except when natural conditions exceed this figure effluents may not increase the turbidity.	Numerical value is inapplicable.	Numerical value is inapplicable.
D. Growth and propagation of fish and other aquatic life, including waterfowl and furbearers.	Same as B-1 to protect associated recreational values.	Greater than 6 mg/l in salt water and greater than 7 mg/l in fresh water.	Between 7.5 and 8.5 for salt water. Between 6.5 and 8.5 for fresh water.	Less than 25 JTU when attributable to solids which result from other than natural origin.	May not exceed natural temp. by more than 2°F for salt water. May not exceed natural temp. by more than 4°F for fresh water. No change shall be permitted for temp. over 60°F. Maximum rate of change permitted is 0.5°F per hr.	Within ranges to avoid chronic toxicity or significant ecological change.
E. Shellfish growth and propagation including natural and commercial growing areas.	Not to exceed limits specified in National Shellfish Sanitation Program Manual of Operations, Part 1, USPHS. (see note 2)	Greater than 6 mg/l in the larval stage. Greater than 5 mg/l in the adult stage.	Between 7.5 and 8.5	Same as D-4.	Less than 68°F.	Within ranges to avoid chronic toxicity or significant ecological change.
F. Agricultural water supply, including irrigation, stock watering, and truck farming.	Mean of 5 or more samples may not exceed 1000 per 100 ml with 20% of samples not to exceed 2400 per 100 ml for livestock watering, for irrigation of crops for human consumption, and for general farm use, except ground water shall contain zero per 100 ml.	Greater than 3 mg/l.	Between 6.5 and 8.5	Numerical values are inapplicable.	Between 60°F and 70°F for optimum growth to prevent physiological shock to plants.	Conductivity less than 750 micromhos at 25°C. Sodium adsorption ratio less than 2.5, sodium percentage less than 60%, residual carbonate less than 1.25 me/l, and boron less than 0.3 mg/l.
G. Industrial water supply (other than food processing).	Same as B-1 whenever worker contact is present.	Greater than 5 mg/l for surface water.	Between 6.5 and 8.5	No imposed turbidity that may interfere with established levels of water supply treatment.	Less than 70°F.	No amounts above natural conditions which may cause undue corrosion scaling, or process problems.

Table 26a

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WATER QUALITY CRITERIA FOR WATERS OF THE STATE OF ALASKA

(7) Residues including Oils, Floating Solids, Sludge Deposits and Other Wastes.	(8) Settleable solids suspended solids (includes sediment & dredge spoil & fill)	(9) Toxic or Other Deleterious. Substances, Pesticides and Related Organic and Inorganic Materials	(10) Color, as measured in color units	(11) Radioactivity	(12) Aesthetic Considerations	Water Quality Parameters / Water Uses
Same as B-7	Below normally detectable amounts	Carbon chloroform extracts less than 0.1 mg/1 and other chemical constituents may not exceed USPHS Drinking Water Standards. (see note 4)	True color less than 15 color units.	The concentrations of radioactivity shall not: a) Exceed 1/30th of the MPCW values given for continuous occupational exposure in the National Bureau of Standards Handbook No. 69. b) Exceed the concentrations specified in the 1962 U.S. Public Health Service Drinking Water Standards for waters used for domestic supplies. c) Have a demonstrable detrimental effect on aquatic life. d) The concentration of radioactive materials in these waters shall be less than those required to meet the Radiation Protection Guides for maximum exposure of critical human organs recommended by the former Federal Radiation Council in the case of foodstuffs harvested from these waters for human consumption. Because any human exposure to ionizing radiation is undesirable, the concentration of radioactivity in these waters shall be maintained at the lowest practicable level.	May not be impaired by the presence of materials or their effects which are offensive to the sight, smell, taste or touch.	Water supply, drinking, culinary and food processing without the need for treatment other than simple disinfection and simple removal of naturally present impurities.
Residues may not make the receiving water unfit or unsafe for the uses of this classification; nor cause a film or sheen upon, or discoloration of, the surface of the water or adjoining shoreline; nor cause a sludge or emulsion to be deposited beneath or upon the surface of the water, within the water column, on the bottom or upon adjoining shorelines.	No imposed loads that will interfere with established levels of water supply treatment.	Chemical constituents shall conform to USPHS Drinking Water Standards. (see note 4)	Same as A-10		Same as A-12	Water supply, drinking, culinary and food processing with the need for treatment equal to coagulation, sedimentation, filtration, disinfection and any other treatment processes necessary to remove naturally present impurities.
Same as B-7	No visible concentrations of sediment.	Below concentrations found to be of public health significance.	Secchi disc visible at min. depth of 1 meter		Same as A-12	Water Contact Recreation
Same as B-7 plus the following: Residues shall be less than those levels which cause tainting of fish or other organisms and less than acute or chronic problem levels as determined by bioassay.	No deposition which adversely affects fish & other aquatic life reproduction and habitat.	Concentrations shall be less than those levels which cause tainting fish, less than acute or chronic problem levels as revealed by bioassay or other appropriate methods and below concentrations affecting the ecological balance.	Same as C-10		Same as A-12	Growth and propagation of fish and other aquatic life, including waterfowl and furbearers.
Same as D-7	No deposition which adversely affects growth and propagation of shellfish.	Same as D-9	Same as C-10		Same as A-12	Shellfish growth and propagation including natural and commercial growing areas.
Same as B-7	For sprinkler irrigation, water free of particles of 0.074 mm or coarser. For irrigation or water spreading, not to exceed 200 mg/1 for an extended period of time.	Less than that shown to be deleterious to livestock or plants or their subsequent consumption by humans.	Inapplicable		Same as A-12	Agricultural water supply, including irrigation, stock watering, and truck farming.
Same as B-7	No imposed loads that will interfere with established levels of treatment.	Chemical constituents may not exceed concentrations found to be of public health significance.	Same as C-10		Same as A-12	Industrial water supply (other than food processing).

Table 26b

and protection of water quality. In attempting to follow the ecological approach, the U.S. Congress ruled that by 1981, the discharge of pollutants into the waters of the nation must be eliminated.

The technologists repeatedly argue that the level of cleanliness sought by the ecologist is "unnecessarily high" for many intended uses and therefore is unnecessarily costly to comply with. The ecologist's retort is that, once pollution is allowed to proceed, the level and the manner of destruction wrought cannot be controlled and that the cost of rehabilitating the water for man's use will continually accrue; by contrast, protecting and maintaining the waters to as close as possible to their natural state, will allow for natural processes to maintain the prime state of quality, at essentially lower long term costs.

The most basic arguments usually revolve around the question of what is the natural "assimilating capacity" of the marine waters for pollutants. Traditionally the technologists have assumed that aquatic ecosystems have the capacity to digest, degrade and ultimately cause to disappear pollutants placed into them. To the ecologists, a functional definition of assimilative capacity is that of the resilience in a natural water body which insures that any changes in the aquatic ecosystem resulting in a physical, chemical or biological change in an unplolluted water body will be of a temporary one, such that within a few hours, days or weeks, the aquatic ecosystem will return to its original functional state. In the ecological approach, such as the one followed by PL 92-500, no reliance is placed upon "assimilative capacity", which directly leads to the conclusion that discharges of pollutants must be eliminated at the source.

The applicability of water quality laws, criteria and standards to the as yet mostly unpolluted status of the marine waters of Kachemak Bay and Lower Cook Inlet needs to be critically examined.

PL 92-500, through its progressive schedule of improved levels of treatment, leading to eventual elimination of pollutant from discharges, aims at repairing and rehabilitating much of the waters already damaged by pollution. The marine waters of the Coast of Alaska, in contrast to most of the coastal waters of the Atlantic, Gulf and part of the Pacific Coast, are for all practical purposes unpolluted and in their prime "pristine" natural quality. The coastal waters of Alaska do not need to be rehabilitated; they only require <u>maximum effective protection</u>, through application of strict, point source prevention of pollutant discharge. For Alaska, the 1981 PL 92-500 goal for elimination of discharge of pollutant is the basic environmental protection goal to be applied today.

In the implementation of PL 92-500, the technologists still exert a dominant control in the implementation of the law through the application of "best treatment technology". To the ecologist however, application of "best treatment technology" raises very serious doubts as to its biological protection effectiveness. Present application of best treatment technology revolves around the levels of treatments that can be achieved by what the regulatory agency considers to be the better performing treatment facilities.

Effluent criteria for the allowable concentration of various classes of pollutants are based upon the ability of best current operating plants to reduce or control the levels of various pollutants. As presently practiced, application of "best treatment technology" considers neither the biological sensitivities of the receiving waters nor the levels of treatments that must be imposed to effectively protect marine life from low level pollution. Numbers such as 25/50 mg of oil concentration in the discharges emanating from production and/or drilling platform are numbers strictly generated by arbitrary statistical manipulation of treatment facilities performance data: such numbers are not based upon biological protection rationales.

To date, even with the available technology and rather large body of environmental laws, the quality and integrity of the marine waters of Alaska must be considered to be virtually unprotected under existing regulatory and enforcement practices.

PL 92-500, in Section 403 (Ocean Discharge Criteria) of the Act, specifies an ecological approach to the drafting of environmental protection guidelines for marine waters. To date, better than establishing specifications for safe transportation, handling, carriage, storage, and stowage of pollutants.

"(h) In the event any condition of a permit for discharges from a treatment works (as defined in section 212 of this Act) which is publicly owned is violated, a State with a program approved under subsection (b) of this section or the Administrator, where no State program is approved, may proceed in a court of competent jurisdiction to restrict or prohibit the introduction of any pollutant into such treatment works by a source not utilizing such treatment works prior to the finding that such condition was violated.

"(i) Nothing in this section shall be construed to limit the authority of the Administrator to take action pursuant to section 309 of this Act.

Public information.

"(j) A copy of each permit application and each permit issued under this section shall be available to the public. Such permit application or permit, or portion thereof, shall further be available on request for the purpose of reproduction.

"(k) Compliance with a permit issued pursuant to this section shall be deemed compliance, for purposes of sections 309 and 505, with sections 301, 302, 306, 307, and 403, except any standard imposed under section 307 for a toxic pollutant injurious to human health. Until December 31, 1974, in any case where a permit for discharge has been applied for pursuant to this section, but final administrative disposition of such application has not been made, such discharge shall not be a violation of (1) section 301, 306, or 402 of this Act, or (2) section 13 of the Act of March 3, 1899, unless the Administrator or other plaintiff proves that final administrative disposition of such application has not been made because of the failure of the applicant to furnish information reasonably required or requested in order to process the application. For the 180-day period beginning on the date of enactment of the Federal Water Pollution Control Act Amendments of 1972, in the case of any point source discharging any pollutant or combination of pollutants immediately prior to such date of enactment which source is not subject to section 13 of the Act of March 3, 1899, the discharge by such source shall not be a violation of this Act if such a source applies for a permit for discharge pursuant to this section within such 180-day period.

30 Stat. 1152. 33 USC 407.

Ante, p. 816.

"OCEAN DISCHARGE CRITERIA

"SEC. 403. (a) No permit under section 402 of this Act for a discharge into the territorial sea, the waters of the contiguous zone, or the oceans shall be issued, after promulgation of guidelines established under subsection (c) of this section, except in compliance with such guidelines. Prior to the promulgation of such guidelines, a permit may be issued under such section 402 if the Administrator determines it to be in the public interest.

"(b) The requirements of subsection (d) of section 402 of this Act may not be waived in the case of permits for discharges into the territorial sea.

Guidelines.

"(c)(1) The Administrator shall, within one hundred and eighty days after enactment of this Act (and from time to time thereafter), promulgate guidelines for determining the degradation of the waters of the territorial seas, the contiguous zone, and the oceans, which shall include:

"(A) the effect of disposal of pollutants on human health or welfare, including but not limited to plankton, fish, shellfish, wildlife, shorelines, and beaches;

"(B) the effect of disposal of pollutants on marine life including the transfer, concentration, and dispersal of pollutants or their byproducts through biological, physical, and chemical processes; changes in marine ecosystem diversity, productivity, and stability; and species and community population changes;

"(C) the effect of disposal, of pollutants on esthetic, recreation, and economic values;

"(D) the persistence and permanence of the effects of disposal of pollutants;

"(E) the effect of the disposal at varying rates, of particular volumes and concentrations of pollutants;

"(F) other possible locations and methods of disposal or recycling of pollutants including land-based alternatives; and

"(G) the effect on alternate uses of the oceans, such as mineral exploitation and scientific study.

Prohibition.

"(2) In any event where insufficient information exists on any proposed discharge to make a reasonable judgment on any of the guidelines established pursuant to this subsection no permit shall be issued under section 402 of this Act.

"PERMITS FOR DREDGED OR FILL MATERIAL

Notice, hearing opportunity.

"SEC. 404. (a) The Secretary of the Army, acting through the Chief of Engineers, may issue permits, after notice and opportunity for public hearings for the discharge of dredged or fill material into the navigable waters at specified disposal sites.

"(b) Subject to subsection (c) of this section, each such disposal site shall be specified for each such permit by the Secretary of the Army (1) through the application of guidelines developed by the Administrator, in conjunction with the Secretary of the Army, which guidelines shall be based upon criteria comparable to the criteria applicable to the territorial seas, the contiguous zone, and the ocean under section 403(c), and (2) in any case where such guidelines under clause (1) alone would prohibit the specification of a site, through the application additionally of the economic impact of the site on navigation and anchorage.

Disposal site, specification prohibition.

"(c) The Administrator is authorized to prohibit the specification (including the withdrawal of specification) of any defined area as a disposal site, and he is authorized to deny or restrict the use of any defined area for specification (including the withdrawal of specification) as a disposal site, whenever he determines, after notice and opportunity for public hearings, that the discharge of such materials into such area will have an unacceptable adverse effect on municipal water supplies, shellfish beds and fishery areas (including spawning and breeding areas), wildlife, or recreational areas. Before making such determination, the Administrator shall consult with the Secretary of the Army. The Administrator shall set forth in writing and make public his findings and his reasons for making any determination under this subsection.

Findings of Administrator, publication.

"DISPOSAL OF SEWAGE SLUDGE

"SEC. 405. (a) Notwithstanding any other provision of this Act or of any other law, in any case where the disposal of sewage sludge resulting from the operation of a treatment works as defined in section 212 of this Act (including the removal of in-place sewage sludge from one location and its deposit at another location) would result in any pollutant from such sewage sludge entering the navigable waters, such disposal is prohibited except in accordance with a permit issued by the Administrator under this section.

four years since the law was passed, EPA, the responsible regulatory agency, has not implemented the ecological requirements of Sec. 403. (403, C 1 and 2). Moreover, by a recent ruling of its General Counsel, EPA (Sept. 8, 1975 Memorandum, as shown) has divested itself of compliance with NDPES permit requirements for drilling vessels and floating drilling structures, vessels and structures most likely to be extensively used in the Cook Inlet and other OCS areas of coastal Alaska.

USGS OCS orders contain some pollution control stipulations; such stipulations however, are environmentally and biologically ineffective.

EPA is presently attempting to develop "interim final effluent guidelines and new sources performance standards for the offshore segment of the oil and gas extraction point source category" (Sept. 1975). Review of the document shows that nowhere are the requirements of Sec. 403 of PL 92-500 even alluded to, nor has any consideration been given to constrain the quality of effluent to the pollutional levels of sensitivities of various marine life as demonstrated by various researchers and results of bioassays. It should be noted here that in effect, the Sept. 8, 1975 ruling by the General Counsel of EPA, negates EPA's efforts to establish and implement the intended effluent guidelines for much of the Coast of Alaska.

The ADF&G, in coordination with NMFS, FWS, EPA and ADEC is attempting

IV-23a

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

file waters Op. 1975

SEP 6 1975

OFFICE OF GENERAL COUNSEL

MEMORANDUM

SUBJECT: ARCO Seismographic Drilling in the Gulf of Alaska

TO: Clifford Smith, Jr.
Regional Administrator

FROM: Robert V. Zener
General Counsel

This is in reference to your request for advice as to the applicability of the FWPCA and the Ocean Dumping Act (Marine Protection, Research, and Sanctuaries Act of 1972) to the activities of ARCO in the Gulf of Alaska.

We understand the facts to be essentially as follows: ARCO proposes to commence seismographic drilling in the Gulf of Alaska. Such drilling will be conducted from a ship located approximately 20 miles offshore and anchored during the period in which drilling will occur. During the course of drilling, discharges of drilling muds and concrete can be expected. The ship, the Glomar Conception, is registered in the United States.

NPDES PERMIT

On the basis of the facts set forth above, Sections 301 and 402 do not apply to the discharges. Section 301 prohibits the "discharge of any pollutant" except as in compliance with enumerated sections. Section 502(12)(B), however, defines "discharge of pollutant" as "any addition of any pollutant to the waters of the contiguous zone or the ocean from any point source other than a vessel or other floating craft." Since the drilling will take place 20 miles offshore the geographic conditions of section 502(12)(B)

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are satisfied. (1) Moreover, the mere fact that the ship will be anchored does not remove it from the class of "floating craft." Thus, there can be no "discharge of a pollutant" within the meaning of the FWPCA and, therefore, no permit under section 402 need be issued. The Agency may not exercise rulemaking authority under the Act in an area in which Congress has withheld jurisdication. Thus, 40 CFR 125.4(a) may not be read to expand, by negative inference, our authority by control pollutants on the high seas.

OCEAN DUMPING PERMIT

While no NPDES permit is required for the exploratory drilling as above described, if discharges of drilling muds, concrete or other materials brought from on-shore facilities will occur, a permit pursuant to section 102 of the Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA) is required. Section 101(a) of the MPRSA provides, in part, that no person shall transport from the United States any material for the purpose of dumping it into ocean waters except as may be authorized by a permit. "Dumping" is defined in section 3(f) as the "disposition of material" and "material" is broadly defined in section 3(c) as "matter of any kind, or description, including ... solid waste, ... chemicals, ... rock, sand ... and industrial waste." Clearly, the drilling mud and cement discharges constitute the "disposition of material" within the meaning of the MPRSA, for which a permit is required.

Robert V. Zener

Robert V. Zener
General Counsel

(1) See the definitions of "territorial seas", "contiguous zone" and "ocean" in section 502(8)(9)(10), respectively.

to formulate effluent limitation criteria based upon existing knowledge of effects of oils upon the marine biota. For Lower Cook Inlet and Kachemak Bay, two areas biological sensitive due to the extent and duration of crustacean larval development, the maximum permissible levels of oil concentration in any discharge must, to be biologically effective, remain within 0.05 and 0.1 mg/l at the point of discharge, such concentrations to be achieved by treatment rather than mixing within a given "mixing zone"; the .05 and 1. mg/l of oil concentration are based upon synthesis of published information on the sensitivity of larval and developmental stages of marine life to hydrocarbons.

Drill cuttings, drilling muds, drilling fluids are unavoidable by-products of any drilling operation. Drilling muds and fluids consist of mixtures of suspended solids, chlorides, alkaline compounds, chromium compounds, bacteriocides, organic polymers, dispersant, defoamers, lubricants and detergents. The toxicity of either the individual components or of the complex "whole" mixture to various forms of aquatic life, especially developmental and larval stages, still needs to be ascertained. The results of a recent EPA sponsored conference on "Environmental Aspects of Chemical Use in Well Drilling Operations" (1975), in which a number of papers dealing with bioassay on drilling muds components were presented and can perhaps be best summarized by the statement by D.G. Wright, a biologist with the Fisheries and Marine Services of Environment Canada: "_ _ _although a great deal of information was exchanged there are a great many questions still unanswered. The conference merely emphasized our lack of understanding of the problem".

Fragmentary information on the toxicity of drilling mud components, stemming from bioassay performed mainly on fresh water fishes, suggests that drilling fluids are toxic to aquatic life. To date, no toxicity measurements have been made on marine juveniles and larval form. Until the toxicity of drilling fluids and muds can be fully ascertained, present ADF&G requirements are for drilling muds and fluids to be fully contained for controlled disposal at an appropriate dump site.

Oil spills, ranging from a few gallons to several hundreds of barrels, are an inevitable consequence of oil and gas exploration, production, transfer and utilization. An interesting and pragmatic discussion of agencies - industry prevention, control and cleanup responsibilities and procedures in Alaska can be found in the master's thesis of R.L. Beving: "Oil Pollution in Maritime Alaska" (1974). A good portion of Beving's thesis discusses the various "oil spill contingency plans".

Control, containment and cleanup of oil spilled into the marine waters of Kachemak Bay and Lower Cook Inlet is an important facet of environmental protection. Section 311 of PL 92-500 establishes a "National Contingency Plan" to "provide for efficient, coordinated and effective action to minimize damage from oil and hazardous substances discharges, including containment, dispersal and removal of oil and hazardous substances _ _ _". The plan requires predesignated on-scene coordinators, requires cooperation and coordination among the various federal, state and local government agencies and the private community. It even requires stockpiling of cleanup equipment in strategic location, for ready availability and deployment. How effectively can the plan and especially the technology of cleanup be applied to the Lower Cook Inlet - Kachemak Bay water is an open question. Except in sheltered areas, the weather, sea conditions, and the speed of the current, are often such that most present containment and cleanup operations must be delayed until the oil reaches the shore. Even so, access to the beaches, cleanup procedures, stockpiling and removal of oil soaked straws and sorbent pads, can only be accomplished under relatively calm conditions.

Perhaps a pragmatic expression of current realities on agencies - industry ability to cope with an oil spill is expressed in Beving's masters' thesis (p. 2):

> "At an August 1972 meeting between the U.S. Coast Guard and EPA officials, it was agreed that in the event of a large spill (2000 barrels or more, 100,000 gallons or more), maximum cleanup effort would have to be put forth because of image propaganda for the public, not because the cleanup attempts would be successful".

In conclusion, all present evidence shows that from a technological and regulatory standpoint, environmental protection of the marine waters of Lower Cook Inlet and Kachemak Bay with respect to pollution threats from oil and gas activities will be, for all practical purposes, ineffectual.

To be effective, environmental protection must be applied at the source, through either prevention of oil and gas activities in highly biologically sensitive and/or areas of high productivity supporting important commercial fisheries, or through imposition of a total moratorium, until the industry - federal - state agencies consortium can demonstrate, to the concerned citizenry,

Requiescat in Pace O Thou Leviathan of the Deep that the best levels of technology will be applied and the laws effectively enforced to insure "fail safe" - "ultra clean" operations.

SECTION V

KACHEMAK BAY

PERSPECTIVE AND OVERVIEW

SECTION V

KACHEMAK BAY

PERSPECTIVE AND OVERVIEW

Any attempt, at this time, to fully assess both the short and long term environmental implications of the intrusion and expansion of oil and gas activities in the biologically rich waters of Kachemak Bay and Lower Cook Inlet, must be tempered by the fact that, key information on the geography of the extent and location of sub-sea floor structures that could be considered as potential traps for hydrocarbons, is not available to the Fish and Wildlife resources agencies.

It is somewhat ironical that, while the Fish and Wildlife resources agencies are requested to provide all available data whenever an "Environmental Impact Assessment" is being prepared for an area the oil and gas interests want to exploit, all of the essential information on the oil and gas resources potentials is withheld from the same agencies under the guise that disclosure of such information would drastically impair industry's competitive edge in bidding for various tracts. Thus in effect, all other resources become subjugated to oil (and/or gas).

The only information available to ADF&G to gauge the potential size of the Kachemak Bay field, as per the 28th lease sale, is the final monetary bidding for each tract. The map (fig. 55), showing the area of highest bids, which by inferrence can be regarded as the potential location of the field, suggests that the extent of the promising structure is rather small, encompassing about 2500 acres.

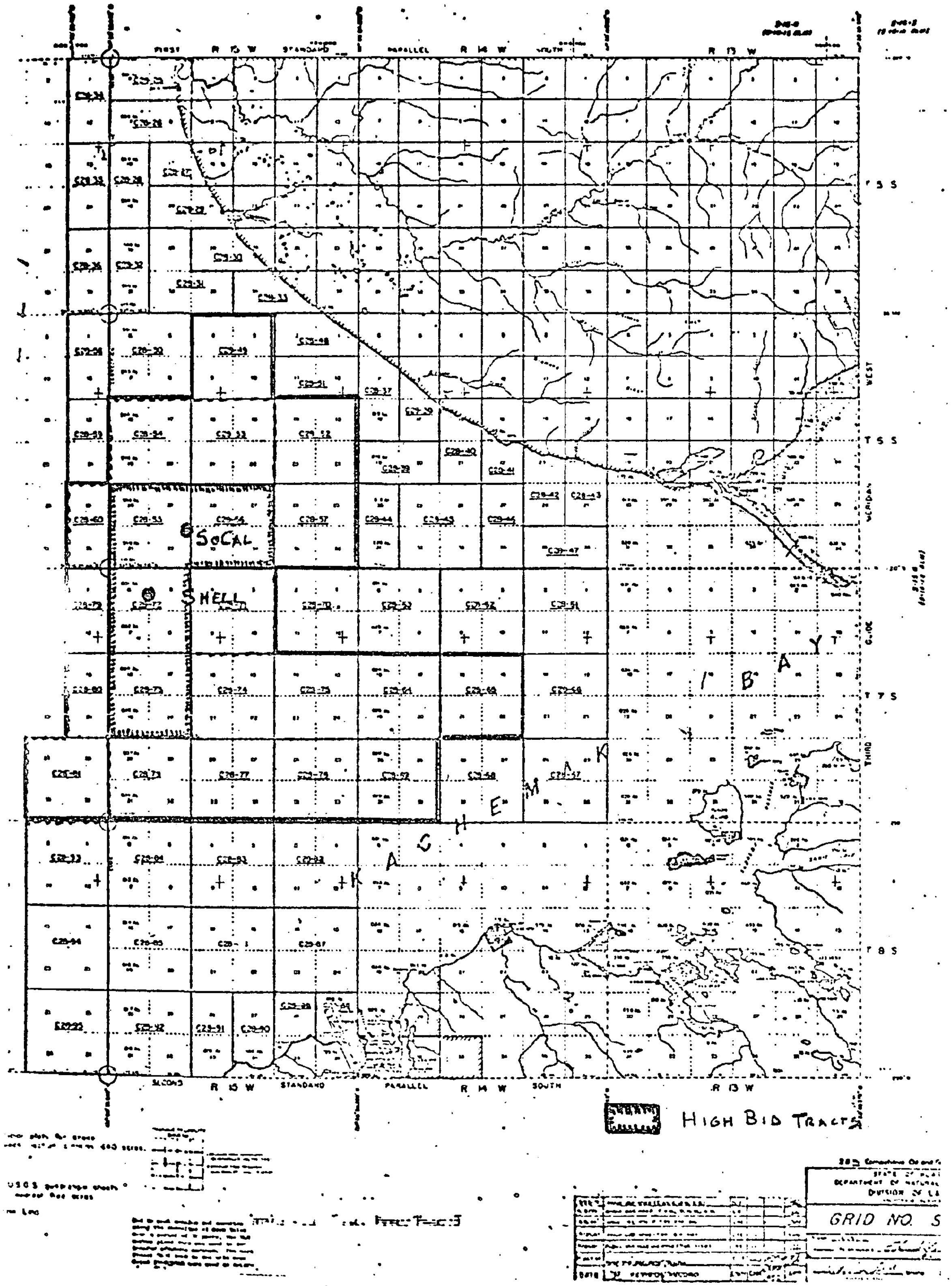

Fig. 55. State of Alaska, 28th Oil and Gas Lease Sale.

The U.S. Supreme Court ruling, allocating much of the waters of Lower Cook Inlet to the federal government, has quickly prompted the opening up of Lower Cook Inlet to oil and gas leasing as shown by the recent DOI/BLM "Proposed OCS Sale No. C 1" (Fig. 56). Of interest is the enclosed news release which clearly infers that the oil companies play the lead role in the decision making for the nomination for tracts. As in the case of Kachemak Bay, the details on the location of the potential structure will not be made available to the resources agencies and the public until the bidding pattern for various tracts has been finalized and made public.

Once such information becomes available, and the area is committed to oil and gas development, then some initial assessment of environmental impact can be made in terms of the evolving scenario of exploration, development, production and transportation, abandonment and rehabilitation. The evolving scenario clearly shows that the impacts must be viewed in cumulative terms and that higher and escalating levels of impacts will occur after oil and/or gas is found and the field proven to be commercial.

The most immediate environmental problems, once leases are sold and authorization is obtained to proceed with exploratory drilling will come from increased vessel traffic and onshore support activites. If exploratory drilling results only in dry holes, then the problem of impacts of oil and gas activities can be relegated to development in more remote areas. If exploratory drilling demonstrates occurrence of hydrocarbons in commercial quantities, the impact will relate to the presence of either an oil, oil and gas or gas field, and until this is determined, assessing future environmental impact is strictly conjectural.

The most basic issue affecting Kachemak Bay is the most basic issue of the time, mainly the quest for "cheap" bountiful supply of energy, quest, as previously mentioned, pursued along a two pronged course:

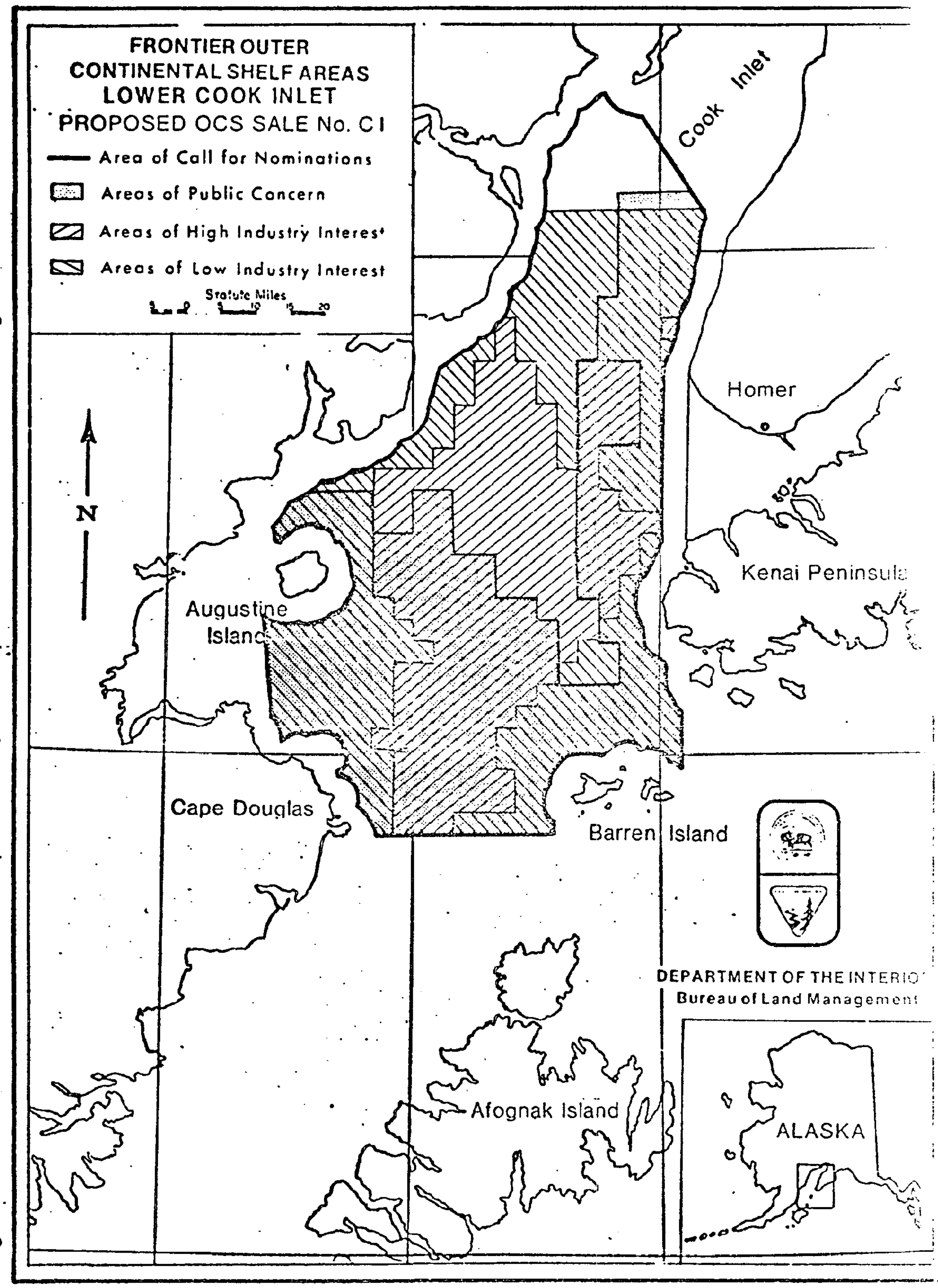

Fig. 56 - Proposed BLM/OCS Oil and Gas Lease Sale, Lower Cook Inlet

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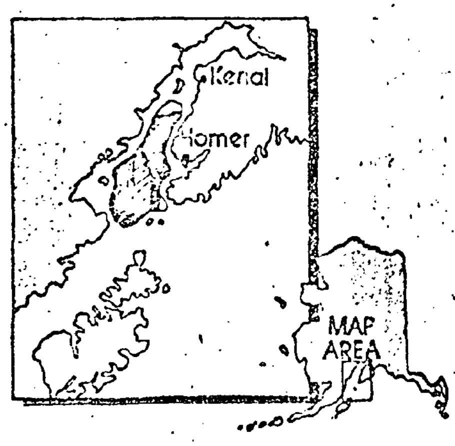
VOL. XXX, NO. 1 36 PAGES ANCHORAGE, ALASKA, FRIDAY, JANUARY 2, 1976 TWENTY FIVE CENTS

Oil companies choose 2.1 million acres



Black area shows tracts nominated for leasing by oil companies in a 450-tract area in Lower Cook Inlet.

By SALLY W. JONES
Daily News Staff Writer

Sixteen oil companies have nominated **2.1 million acres** *for offshore oil development in Cook Inlet.*

The Department of Interior called for the nominations in a 2.3 million-acre area in the inlet in September, and set the deadline for nominations for November 17. A spokesman for Interior's Outer Continental Shelf (OCS) Office said Alaska OCS Manager Edward Hoffman has forwarded recommendations to Washington on the tracts that should be leased this fall. The spokesman said the tracts Hoffman identified for leasing are not public record at this time. The U.S. Geological Survey also is to recommend tracts for leasing.

THE AREA being considered for oil and gas lease sale is located at the lower end of Cook Inlet, generally south of Kenai.

Nine groups, including private organizations and government agencies, also responded to the call for nominations and cited from 48 to 157 tracts that should not be considered for a lease sale because of their location in the *midst of fishery resources, critical bird and seanmammal* habitats, and hazardous seismic zones.

None of the tracts nominated by the oil industry is closer than three miles from shore and some lie as far as 26 miles offshore in an area 58 miles wide and 87 miles long. In all, 433 of the 450 tracts identified in the call were nominated for leasing.

THE OIL COMPANIES showed highest interest in 192 tracts located in the central portion of the 450-tract area. All but 48 of the high-interest tracts lie in areas the nine government and private groups cited as sensitive.

Although the OCS office would not comment Wednesday on the tracts that Hoffman has recommended for leasing, Hoffman has met with representatives of the state of Alaska and three federal agencies to discuss the call area.

Hoffman said the meeting was called to keep the state "involved in the total OCS process." The meeting was held Nov. 16 but onshore impacts from OCS development were not discussed, said Hoffman.

HOFFMAN SAID comments he received from groups other than the oil industry were "specific as to precise tracts which the concerned groups feel should not be leased. When we know such facts in advance, we are better able to seek substantiating evidence of claims such as the *interference* with established fisheries or potential evironmental hazards."

Hoffman said earlier this month his recommendations on *which tracts* should be leased would be based on all comments received following the September nomination call.

Nominations for leasing came from Gulf Oil Co.; Marathon Oil Co.; Getty Oil Co.; Exxon Co., USA; Louisiana Land and Exploration Co.; Atlantic Richfield Co.; DEPCO, Inc.; Mobile Oil Corp.; Shell Oil Co.; Phillips Petroleum Co.; Union Oil of California; the Oil Development Co. of Texas; Texas Gulf Co.; Cities Service Co.; Standard Oil of California and the Amoco Production Co.

THE U.S. COAST GUARD commented that offshore leasing in the inlet should take into account increased vessel traffic in the Kachemak Bay area.

The U.S. Fish and Wildlife Service and Alaska Department of Environmental Conservation identified sensitive wildlife areas.

Comments also were received from the Board of Fisheries Advisory Committee in Homer; the North Pacific Fisheries Association and the Kachemak Bay Defense Fund. The groups pinpointed critical commercial fisheries areas in the nomination call area.

THE ALASKA Conservation Society also noted sensitive sea bird and fisheries areas; and the National Marine Fisheries Service said "the entire area of the lower Cook Inlet is productive" *for commercial fishing.*

Hoffman's and the geological survey's recommendations will be used to formulate Interior's proposal for specific tracts to be considered for OCS leasing. Once Interior decides *upon the tracts and environmental impact statement will be,* written and form the basis for the tracts that are selected for oil and gas industry bids.

The Department is scheduled early this year to open bidding for offshore oil leases in the Gulf of Alaska. The state *has been critical of the gulf sale, arguing it is being held too* hastily before all impacts and effects are addressed.

1. Energy to do mechanical work and provide for creature comfort, in the form of hydrocarbons, electrical, atomic energy generating devices.
2. Energy to sustain life, in the form of food.

To put the resources conflict issues of Kachemak Bay in perspective, let us consider man's needs and uses of energy in a different context and refer to the substance of enclosures 1 through 4. Let us look as the food energy side of the escalating national (and international) energy dilemna.

If one begins to look at food as part of man's total energy budget, and consider how much energy must be supplied to provide a unit of food energy, the substance of enclosures 1 and 2 serve to underscore the key issues of the energy problem, mainly that the so called advanced countries can produce, process, transport and sell food in abundance and relatively cheaply as long as such food can be produced and made available through a large and cheap energy subsidy.

The magnitude of present energy demands to provide food stuff in the U.S. is perhaps best expressed in a statement in 1974 Science article by Steinhart and Steinhart:

> "In 'primitive cultures', 5 to 50 food calories are obtained for each calorie of energy invested. In sharp contrast, industralized food systems require 5 to 10 calories of fuel to obtain 1 food calorie."

Enclosure 2 aptly summarizes the magnitude of "energy subsidy" involved in producing common staples.

A second major, and perhaps more ubiquitous issue, rests with the fact that American agriculture is an agrochemical agriculture geared to produce large volumes of grains of steadily decreasing balanced nutritional values through the cultivation of "high yield hybrids" (Enclosure 3). Due to their

Food costs counted in energy terms

By BRUCE JOHANSEN

With the help of a recently issued report, energy conservationists now may count their British Thermal Units, as well as their calories, as they eat.

The report, issued by the Center for Science in the Public Interest, analyzes the amount of energy required to produce, package and peddle various food items.

IN ADDITION, the report states, energy requirements for food generally rise with the degree of processing, while nutritional value falls.

"Good energy conservation practices . . . are compatible with good nutrition and good consumer-buying practices," the report's authors, Dr. Albert Fritsch, Linda Dujack and Douglas Jimerson, assert.

"A considerable portion of the energy expended in food production occurs in the packaging. High-energy users include such processed food items as aerosolized cooking oil, flavorings and spreads, TV dinners, frozen prepared foods and canned beverages," the report states.

Consumers who want to place themselves on an "energy diet" should follow five steps, the authors recommend:

—Start a home garden and/or orchard. Home-grown lettuce requires 1,750 B.T.U. a pound; store-purchased lettuce requires 5,200, most of the difference coming in transportation and retailing energy costs, such as truck fuel and lighting for a supermarket.

—Shift to vegetable from animal sources, especially from grain-fed beef. A pound of meat protein requires about four times the energy of a pound of plant protein. Grain-fed beef requires about 30 per cent more energy than grass-fed beef. Poultry requires about half the energy expenditure of grain-fed beef.

—Reduce use of processed foods, especially frozen ones.

— Avoid non-returnable bulk and unprocessed foods.

—Increase purchase of beverage containers. Frequent stores which allow customers to bring their own containers, such as co-ops.

THE MOST energy-intensive of all edible products surveyed in the report were distilled spirits, which require 85,300 B.T.U. a gallon to produce, transport, package and sell.

Ironically fish, often recommended by nutritionists, consumes more energy a pound than any meat product, according to the report, which says one reason is the large amount of energy required to fuel fishing fleets.

Packaging and freezing of fish for consumption away from coastal areas may add to the energy cost of fish and fish products.

Canned salmon, for example, requires 51,150 B.T.U. a pound, more than grain-fed beef, which takes 42,600.

In total, the United States consumed more than nine calories in energy to produce each calorie in food value, according tothe report.

"THESE inefficiencies are subject to critical examination in an energy-short world," the authors contend.

The United States also has been exporting "energy-intensive" agriculture through the so-called "Green Revolution," the report contends.

"The Green Revolution has compounded the problem since it substituted chemical fertilizer-intensive grain types for more hardy but less productive varieties," it said.

Much of the reason for rising food prices in recent years is rising energy costs, and the rising amount of energy required to produce increasingly processed and overpackaged food items, according to the study.

"While in the past energy never amounted to more than a cent or so of each food dollar, the picture is changing due to rising energy cost," it said.

The report said that the United States now uses about 12 per cent of its energy budget to produce or prepare food.

UNITED STATES agriculture, among the world's most productive in terms of yields, also is very energy-intensive.

The most obvious reason, according to the report, is the continuing substitution of machine power for human and animal muscle in the fields.

Less obvious reasons include energy used to manufacture fertilizers, despite the fact that nitrogen can be "fixed" in soils through rotation of legume crops with others.

Another "hidden energy cost" is irrigation pumping, the report said.

And, as more crops are transported greater distances to markets, transportation-energy costs rise, too, the report said.

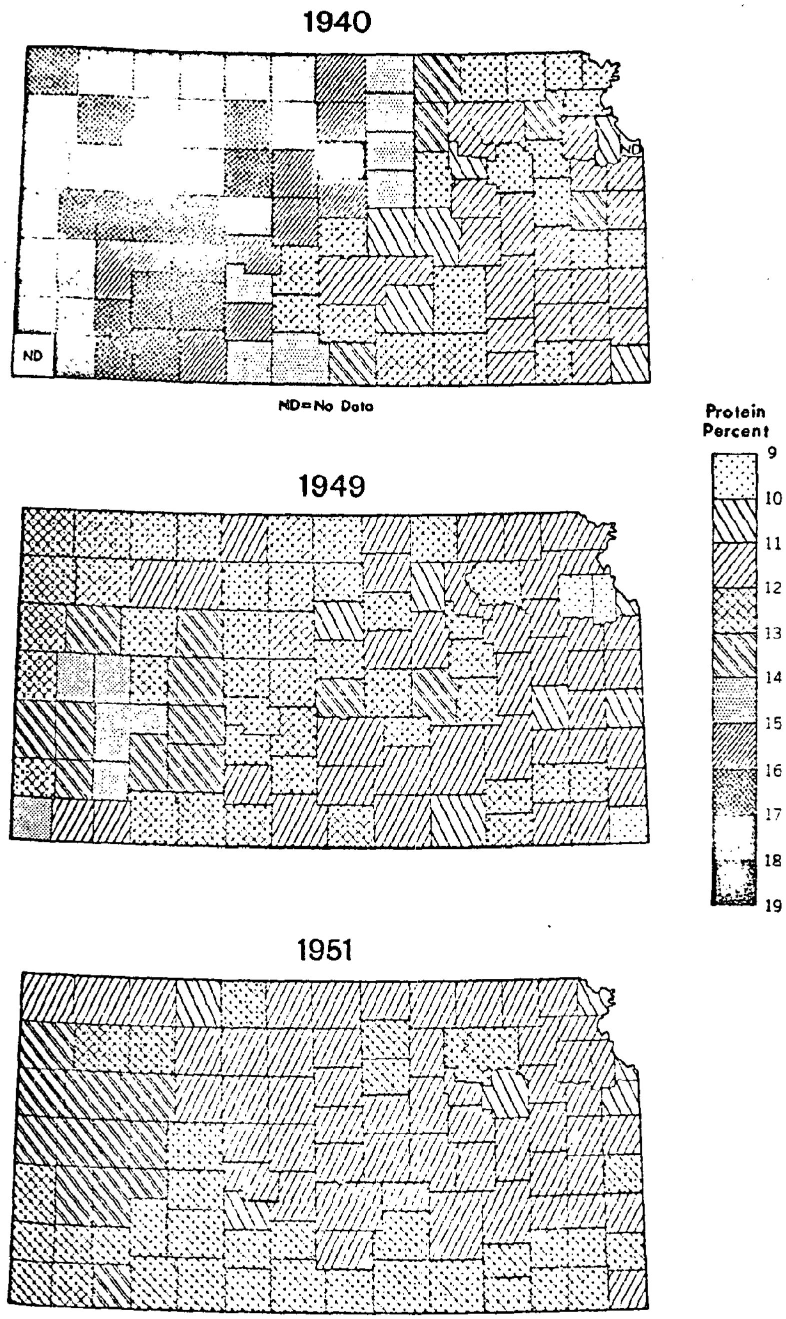
Enclosure 1

Food cost in energy terms

How much energy is required to produce, prepare and sell the foods you eat? A sampling of some common items follows, from a report compiled by the Center for Science in the Public Interest:

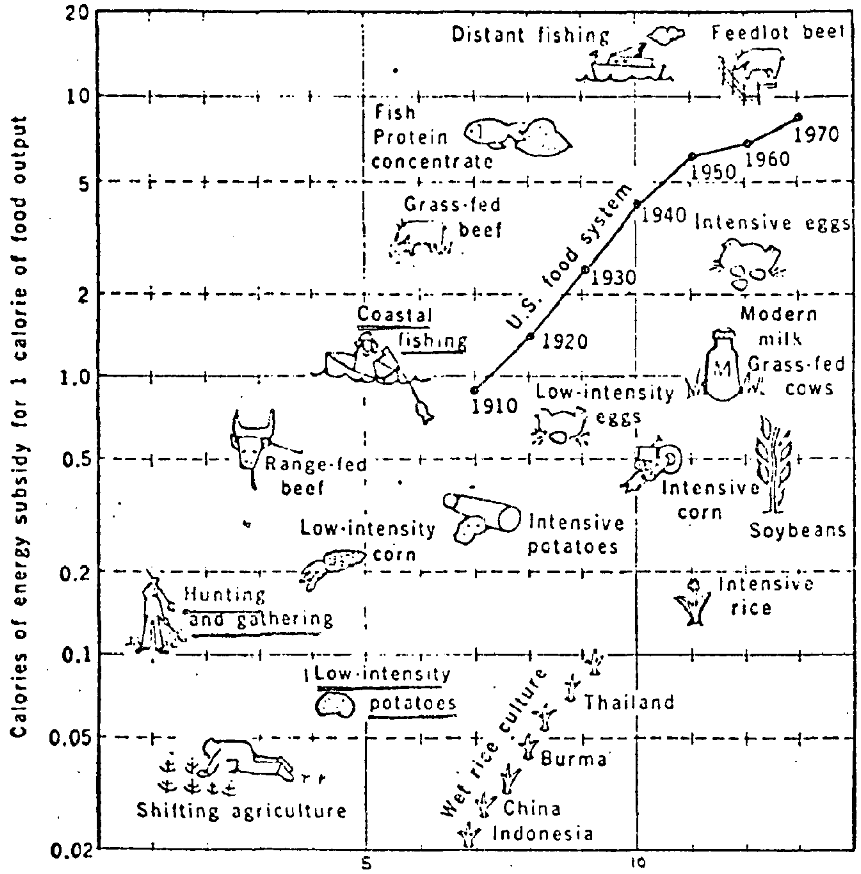
Beef: grass or forage fed:		29,650	British Tremal Units a pound.
Beef: grain-fed:		42,600	" " "
Pork		29,400	" " "
Chicken		19,150	" " "
Turkey		21,400	" " "
Eggs		31,950	B. T. U. a dozen
Cheese		47,550	B. T. U. a pound
Ice Cream		23,100	" " "
Fluid milk		6,810	B. T. U. a pound
Canned salmon		51,150	B. T. U. a pound
Canned tuna		51,300	B. T. U. a pound
Fresh or frozen fish (average)		58,538	B. T. U. a pound
Cantaloupe	(fresh)	5,750	B. T. U. a pound
Carrots	(fresh)	4,750	B. T. U. a pound
Sweet Corn	(fresh)	5,250	B. T. U. a pound
Apples	(fresh)	5,950	B. T. U. a pound
Oranges	(fresh)	7,500	B. T. U. a pound
Corn	(canned)	10,300	B. T. U. a pound
Carrots	(canned)	9,200	B. T. U. a pound
Wheat bread		8,300	B. T. U. a pound
Pies		16,600	B. T. U. a pound
Cookies		12,700	B. T. U. a pound
Distilled liquor		85,300	B. T. U. a gallon
Wine		27,600	B. T. U. a gallon
Soft drinks		24,440	B. T. U. a gallon

ENCLOSURE 2



The concentration of crude protein in the wheat of Kansas, by county averages, has been declining during successive years of sampling.

(Albrecht, W.A., 1971)



Energy subsidies for various food crops. The energy history of the U.S. food system is shown for comparison. [Source of data: (51)]

(From: Steinhart and Steinhart, 1974.)

diminished "balanced nutritive" values, consumption of high yield grains requires protein supplement to insure balanced nutritional requirements.

Agrochemical agriculture requires large amounts of fertilizers, and the usually less disease or insect resistant hybrids require large applications of insecticides and pesticides all mostly manufactured from hydrocarbons.

Thus the escalating scarcity in the ready availability and supply of hydrocarbons is initiating a total change in man's ability to feed himself on a regional, national and global scale.

Returning to Kachemak Bay, one can see that the highly protein rich fisheries resources will rapidly escalate in human values as the artifically maintained agrochemical system begins to break down due to the increasing scarcity of abundant, <u>cheap</u> hydrocarbon energy.

Examination of the graph of enclosure 4 demonstrates the values of local fishing and local agriculture, close to the centers of needs, in terms of energy budget. Distant fishing is highly "energy subsidy" dependent. It might be selfish interest to note that, limiting the sharing of oil with others might reduce the intensity of foreign fishing off Alaska's coast. Coastal fishing is much less energy consumptive. Of interest to the citizens of Alaska are the energy requirements for "low" and "high" intensity cultivation of potatoes, a tuber readily adapted to growing in the Kachemak Bay area and other locations in South Central Alaska. Thus, the combination of the high renewable seafood energy reservoirs of the waters of Kachemak Bay and Lower Cook Inlet, coupled with high agricultural potentials of nearby land makes the area potentially capable of providing a good portion of the basic food energy requirements for most of the present population of South Central Alaska. As the availability and especially cost of transporting basic food stuff from distant sources becomes excessive due to petroleum energy scarcity and cost, the ability of the area to self support its citizens will dramatically escalate in value.

For environmental and resources planning, management, conservation and protection actions, Kachemak Bay cannot be separated from Cook Inlet. The development of a long term conservation and management plan for the fisheries (protein) resources of Kachemak Bay will have to be implemented as part of an integrated resources management and environmental quality protection plan for the entire Cook Inlet area.

Preliminary results from ADF&G circulation studies strongly underscore that the Kachemak Bay environment is intimately tied to the environment of Lower Cook Inlet. From a marine water quality standpoint, Kachemak Bay, is in an environmentally privileged situation, being on the "upstream" portion of inflowing clean, unpolluted ocean waters. Recent results from drift measurements indicate that Kachemak Bay is continuously being flushed, if sometimes sluggishly by clean ocean water; 30 days appears to be a maximum length of time for residence of water in the outer bay. Through strict environmental control of compatible users, the "upstream" location and flushing attributes of Kachemak Bay can insure long term maintenance of its high natural level of environmental quality.

In contrast, as shown in Figure 59, the net circulation of Cook Inlet will tend to carry pollutants towards its southwestern shore, as shown, the Kamishak - Chinitna side acting as a pollution trap for both acute and chronic, cumulative pollution. The Kamishak - Chinitna Bay side of the inlet is a biologically rich and productive area, requiring utmost protection.

All evidences also point to the fact that the entire Lower Cook Inlet is a highly rich, productive and sensitive biological area. Lower Cook Inlet warrants the best environmental protection possible to preserve its increasingly high seafood values. Very serious considerations should be given to putting the entire lower Cook Inlet area as delineated in Figure 60, into some form of a

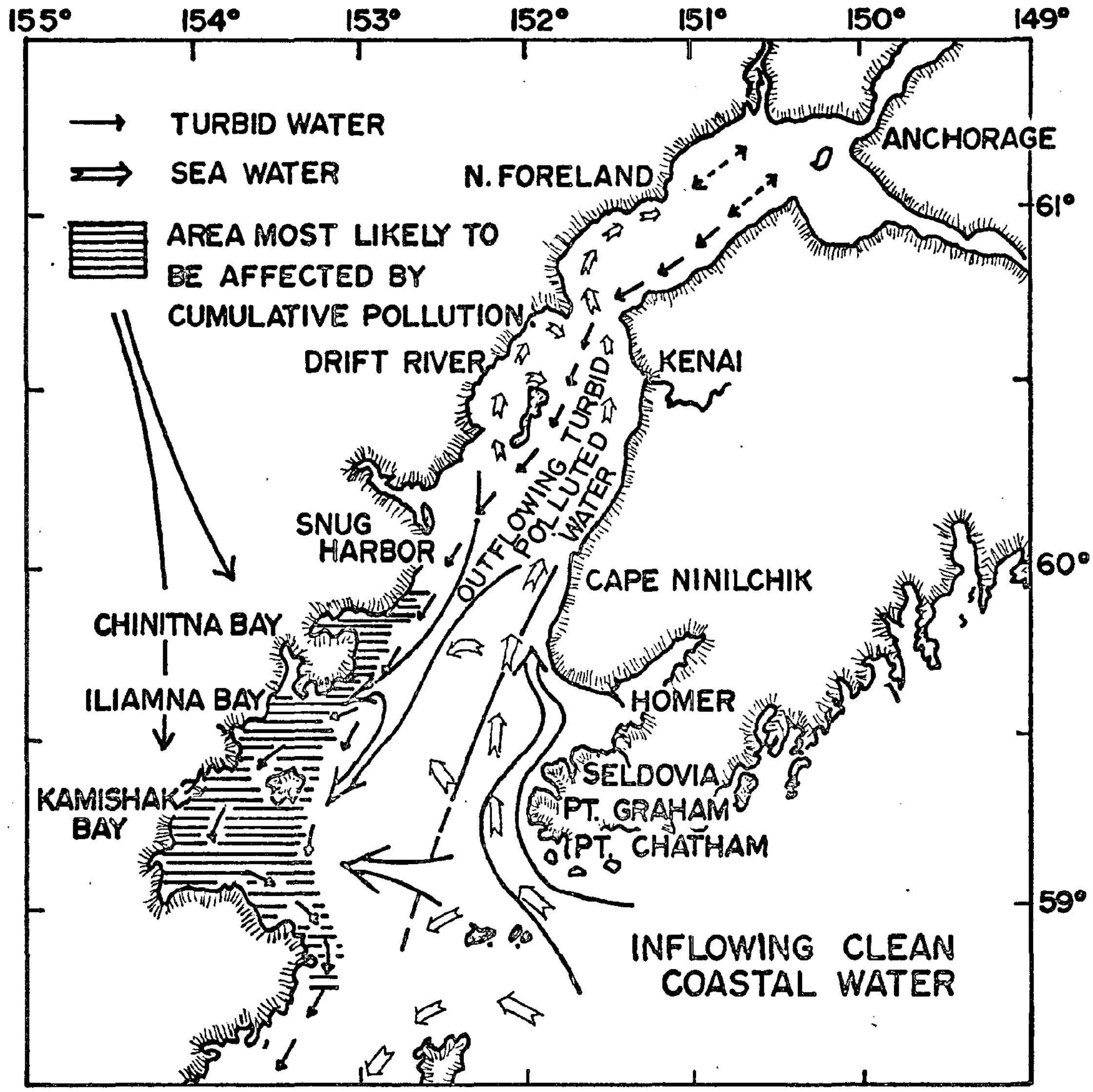


Fig. 59 - COOK INLET: INFERRED CIRCULATION AND POLLUTION TRANSPORT

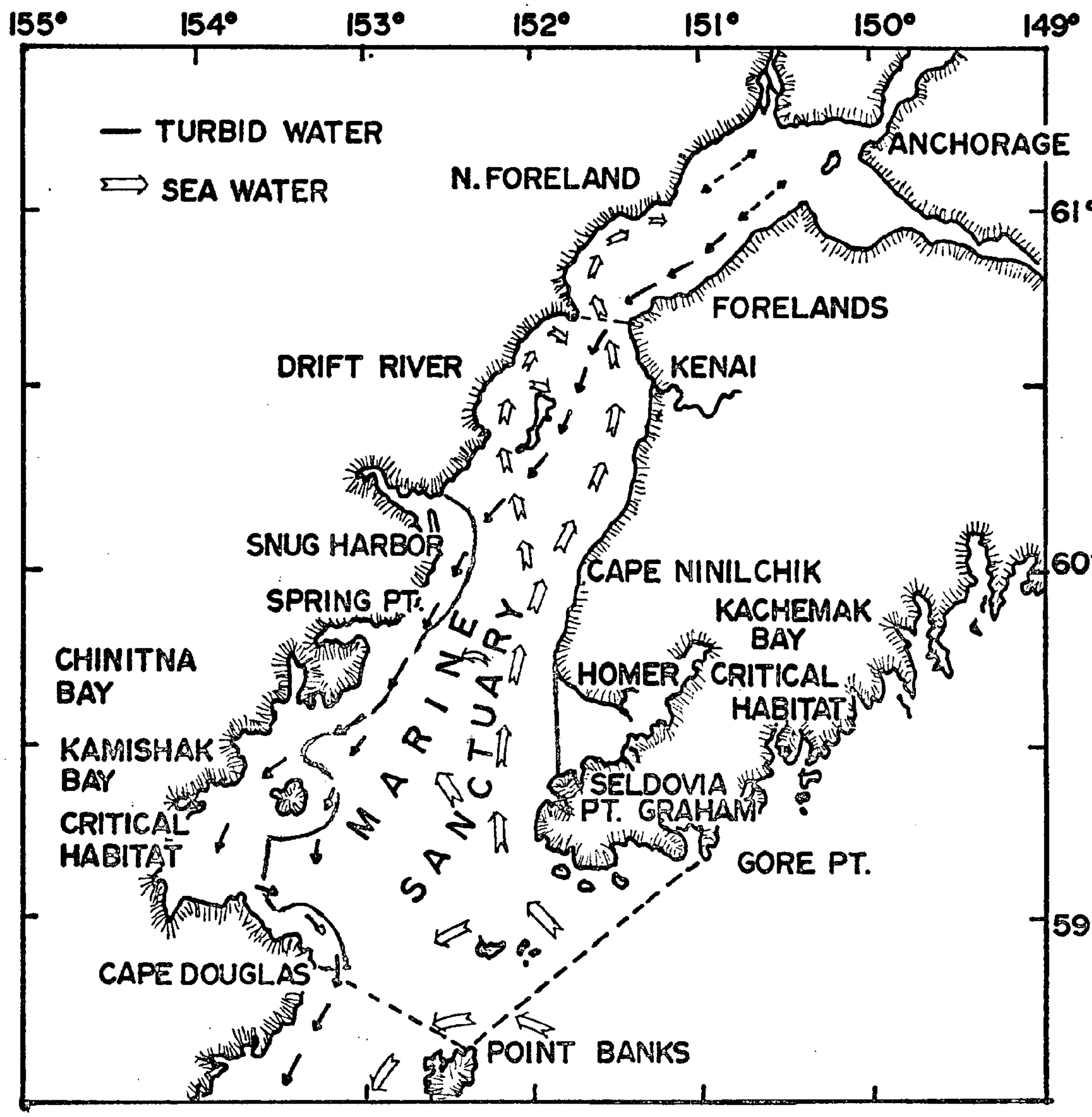
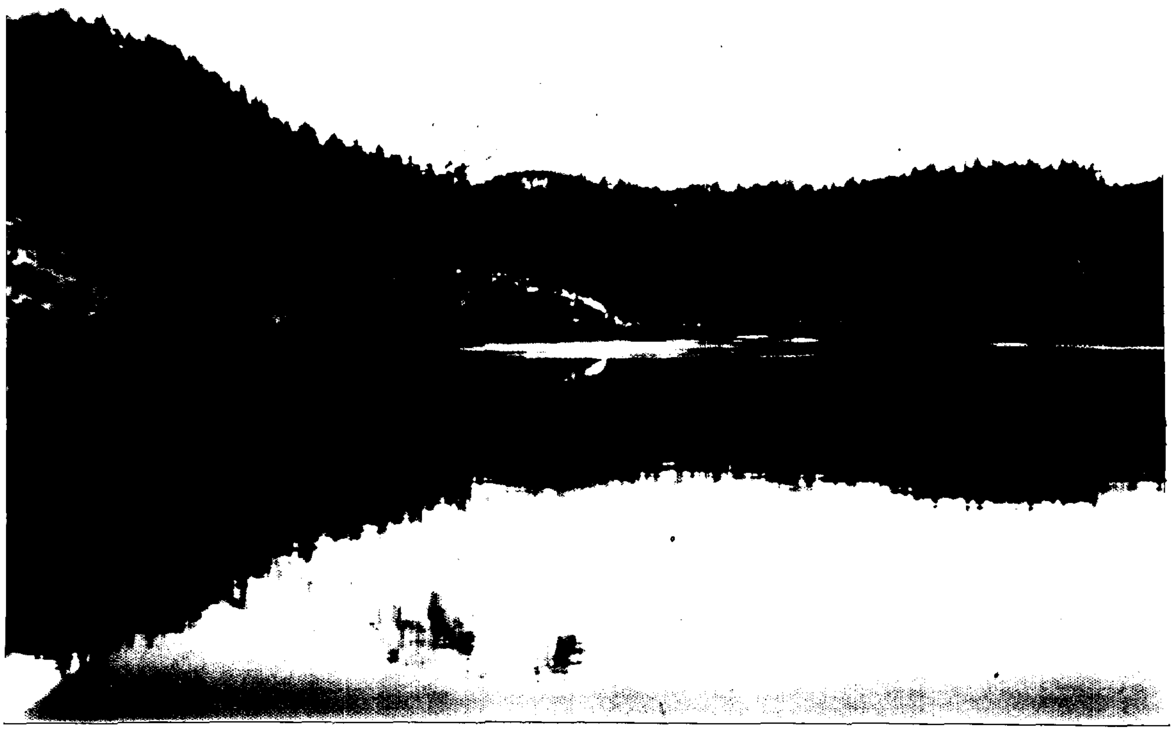


Fig. 60 - COOK INLET MARINE SANCTUARY AND CRITICAL HABITATS



Reflections

marine sanctuary status. In addition, two Critical Habitat areas should be set aside to better further the protection of critical biological areas from non-compatible resource use and insure that the biological resources of the area are given dominant priority in any contemplated resources use.

The Marine Sanctuary portion of the inlet would not per se necessarily bar oil and gas development. The industry however, would not be able to enter the area until totally new technologies for environmental protection have been developed (as fully containing drilling and well sites within completely sealed enclosures, shipping all wastes to treatment facilities which would provide "zero" pollutant discharges, location of shore facilities, outside Critical Habitats).

The main emphasis of any future action, in both Kachemak Bay and Cook Inlet must be placed upon <u>protection</u>, through immediate enforcement of the most advanced and stringent environmental protection technology. Baseline studies can be pursued <u>ad infinitum</u>, but availability of results from such studies however, lag much behind the continuing demands placed upon the natural resources. Present actions must make use of best current available knowledge to argue for the imposition and application of highest levels of control and prevention technology.

Seemingly drastic measures, such as abrogating the use of Kachemak Bay as a source for hydrocarbons can be a first bold move in balancing the long term values of other essential human resources against seemingly short term gains to nurture a breaking down "energy subsidy" system.

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